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EMISSION FACTORS FOR GRAIN RECEIVING & FEED LOADING OPERATIONS AT FEED MILLS

Submitted to:

National Cattleman's Beef Association

by

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EXECUTIVE SUMMARY

The Federal Clean Air Act (FCAA) signed by President Bush in 1990 has impacted the process used by State Air Pollution Regulatory Agencies (SAPRAs) in regulating air pollution attributed to grain handling facilities including feed mills associated with cattle feed yards. The AP-42 total suspended particulate (TSP) uncontrolled emission factors for feed mills published by EPA in 1988 are not accurate. EPA published interim emission factors for grain elevators in 1995. The two operations that will result in particulate entrainment at feed mills and grain elevators are grain unloading and shipping (loading) of grain and feed from the elevator or mill, respectively. Feed mill unloading and loading operations are different. Due to the differences between elevator and feed mill unloading and loading operations and the lack of data on emission rates of feed mills, accurate and scientifically justifiable emission factors for feed mills are required.

The objectives of this feed mill emission factor study were:

- To measure the TSP and PM-10 emission rates resulting from grain unloading and feed loading operations.
- To calculate accurate emission factors for grain unloading and feed loading operations; and
- To propose new emission factors for grain unloading and feed loading operations.

Dust sampling was conducted at three feed mills (located in Nebraska, Kansas and Texas). These mills were representative of small, medium, and large capacity mills associated with the cattle feeding industry.

The sampling protocols included the following:

(1) Enclosing the area under the grain trucks and above the feed trucks and measuring the total mass of dust suspended in air. The ratio of mass collected to tons of grain or feed, unloaded or loaded, respectively, yielded emission factors.

(2) The concentration leaving the shed was measured at three different heights (3, 6 and 9 feet). With the concentration measurements and the volumetric rate of flow through the shed during the sampling period, a measurement of particulate mass was obtained. The ratio of particulate mass and tons unloaded or loaded yielded measurements of emission factors.

Table ES1 includes EPA's interim emission factors for unloading and shipping grain and corn at country elevators, and the average and standard deviations of TSP and PM-10 emission factors for grain unloading and feed loading at feed mills determined from this research.

Table ES1: Emission Factors for Grain Unloading and Shipping at Grain Elevators (AP-42, EPA, 1995b) and Emission Factors for Grain Unloading and Feed Loading at Feed Mills Resulting from this Study.

Emission Factor (lbs/ton)	AP-42 Interim for Grain Elevators				Results of this Study for Feed Mills			
	TSP		PM-10		TSP		PM-10	
	general	corn†	general	corn†	avg	std dev	avg	std dev
Grain Unloading	0.06DR	0.15	0.015DR	0.0375	0.0166	0.0177	0.0025	0.0027
Feed Loading	0.011DR*	0.0275	0.003DR*	0.0075	0.0033	0.0016	0.0008	0.0007

* Emission factor for grain shipping would have been used for feed loading at feed mills since no data for bulk loading at feed mills existed prior to the completion of this research.

† Based on a dustiness ratio (DR) for corn of 2.5.

It is recommended that EPA adopt a new model for calculating the emission factors associated with feed mills:

$$EF = F \cdot FFD \qquad \text{(EQ ES1)}$$

where, EF = Emission Factor (lbs/ton),
F = fraction of free fine (less than 100μm) dust present in grain entrained in air, and
FFD = free fine dust present in grain (lbs/ton).

This model has the advantage of being dependent on measurable properties of the grain or feed. Parnell (1988) measured the FFD of a number of grains and the values closely correspond to the EPA DR values i.e. 2.5 lbs/ton for corn, 1 lbs/ton for wheat, etc. Hence, it is proposed that the DR values be used as the FFD values for different grains.

Table ES2 is our recommendation for emission factors for feed mills associated with cattle feed yards. These values are a sum of the average measured emission factors plus one standard deviation.

Table ES2: Proposed Emission Factors for Unloading Grain and Loading Feed at Feed Mills Associated with Cattle Feed Yards with FFD = DR.

Emission Factors (lbs/ton)	TSP General	TSP For Corn[†]	PM-10 General	PM-10 For Corn[†]
Grain Unloading	0.016*FFD	0.04	0.0024*FFD	0.006
Feed Loading	0.002*FFD	0.005	0.0006*FFD	0.002

[†] Based on FFD = 2.5 lbs/ton for corn.

Table ES3 illustrates the anticipated emission rates (EQ. ES1) for grain unloading and feed loading at a feed mill for various grains. The FFD contents were assumed to equal the dustiness ratios reported in the AP-42 Interim report.

Table ES3: TSP and PM-10 Emission Factors for Unloading Various Grains and Loading feed at Feed Mills

Grain	Dustiness Ratio (DR)	TSP		PM-10	
		Grain Unloading	Feed Loading	Grain Unloading	Feed Loading
Corn	2.50	0.040	0.005	0.006	0.002
Wheat	1.00	0.016	0.002	0.002	0.001
Milo	1.75	0.028	0.004	0.004	0.001
Soybean	2.50	0.040	0.005	0.006	0.002
Mixed	1.95	0.031	0.004	0.005	0.001

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EMISSION FACTORS FOR GRAIN RECEIVING & FEED LOADING OPERATIONS AT A FEED MILL

INTRODUCTION

Overview

The Federal Clean Air Act (FCAA) signed by President Bush in 1990 has impacted the process used by State Air Pollution Regulatory Agencies (SAPRAs) in regulating air pollution attributed to grain handling facilities including feed mills associated with cattle feed yards. The most significant impact is the requirement that all sources of air pollution designated as major sources will be required to pay TITLE V annual emission fees of approximately $30 per ton of emissions and obtain a Federal Operating Permit (FOP). Major sources in attainment areas are those emitting more than 100 tons of a criteria pollutant per year. In nonattainment areas, facilities emitting less than 100 tons of a criteria pollutant may be designated a major source. AP-42 emission factors are typically used to estimate the annual emission rate of a source of pollution. The emission factors for grain elevators and feed mills (EPA,1988) were not correct. (See **Table 1**).

<u>Table 1: EPA AP-42 Total Suspended Particulate (TSP) Uncontrolled Emission Factors for Feed Mills (1988)</u>

Type of Operation	Emission Factor (lbs/ton)	
	Country Elevator	Feed Mill
Unloading (receiving)	0.6	2.5
Loading (shipping)	0.4	1.0
Removal from bins (tunnel belt)	2.0	---
Drying	0.2	---
Cleaning	0.4	---
Headhouse (legs)	5.0	---
Handling	---	5.5
Hammermilling	---	0.2
Flaking	---	0.2
Cracking	---	0.02
Pellet Cooling	---	0.4
Total	8.6	9.82

For example, the total emission factor in AP-42 for a feed mill was 9.82 pounds of total suspended particulate (TSP) per ton of grain (lbs/ton). For a 20 ton per hour (t/hr) mill, operating 16 hours per day, 365 days per year, a total of 116,800 tons of grain/feed will be processed. A 9.82 lbs/ton emission factor suggests that the mill will emit 574 tons of particulate (TSP) per year. There was some speculation that the TITLE V emission fees would be determined by multiplying the total number of tons of particulate (TSP) emitted per year by the TITLE V emission fee rate ($30/ton). For this example, the TITLE V annual emission fee would have been $17,220.00. In a policy document to SAPRAs, EPA (1995b) designated particulate matter less than 10 micrometers (PM-10) as the criteria pollutant for particulate. This policy established that the annual emission rate of PM-10 would be used to determine if a grain elevator or feed mill would be a major source and would be the value of annual emissions used to establish the annual TITLE V emission fees.

EPA recognized that there were errors in the 1988 emission factors for grain elevators and feed mills and published interim factors for country elevators (EPA,1995d). See Tables 2 and 3. The major changes for animal feed mills was changing the emission factors associated with Handling, Hammer milling, Flaking, Cracking, and Pellet cooling in Table 1 to 0 when estimating the total TSP emission rate. *"For smaller animal feed mills located at cattle feedlots, the most significant emission sources are grain unloading and bulk loadout. Material preparation/milling operations, (i.e., flaker, grain cracker, and mixing) are enclosed operations."* (EPA, 1995d). In addition, the PM-10 dust content of grain was listed as 25% of total suspended particulate in the interim AP-42 publication.

__Table 2: Interim Uncontrolled Total Suspended Particulate Emission Factors for Grain Elevators (1995d)__

Type of Operation	TSP† lbs/ton	PM-10† lbs/ton
Receiving (unloading)	0.060 x DR	0.015 x DR
Shipping (loading)	0.011 x DR*	0.003 x DR

* The emission factors for grain shipping were included in this interim AP-42. No data for bulk loading at feed mills was available. These interim emission factors were based on the results of the study conducted by Kenkel & Noyes (1995).

† The term DR in this table refers to dustiness ratios relative to wheat.

Table 3 contains the calculated average ratio of dust generated by soybeans, corn, or milo, relative to wheat. The "mixed grains" DR value is an average of the DR values for the other grains.

Table 3: Dustiness Ratio (DR) Values for Different Grains Reported by EPA (1995d)

Grain	Relative Dustiness (lbs/ton)
wheat	1.0
soybeans	2.5
corn	2.5
milo (sorghum)	1.75
mixed	1.95

The interim emission factor for unloading corn would be 0.15 lbs/ton (0.06*2.5). (See Tables 2 and 3)

The interim AP-42 for country grain elevators (Tables 2 and 3) would result in TSP emission factors of 0.15 lbs/ton for grain unloading and 0.04 lbs/ton for grain loading for a total emission factor of 0.19 lbs/ton. No data exists for grain unloading and feed loadout for feed mills associated with cattle feed yards. If 0.19 lbs/ton were to be used for the 20 ton/hour mill operating for 16 hours/day, 365 days/year, 11 tons of TSP would be emitted per year from these two operations. Approximately 3 tons/year would be PM-10. This resulting PM-10 emission rate would suggest that this mill would not be a major source. The problem is that no data exists to demonstrate that the emission factors for animal feed mills are similar to emission factors for country elevators. If SAPRAs were to use just the 1988 emission factors for feed mills associated with unloading of grain and loadout of feed (3.5 lbs/ton), an annual TSP particulate emission rate of 204 tons would result. In some states, facilities are being required to pay annual air pollution fees based upon annual emission rates irrespective of whether they are classified as a major source. Feed mill emission factors are needed to replace the 1988 emission factors.

The National Cattleman's Beef Association funded the Department of Agricultural Engineering at Texas A&M University to gather data that could be used to establish emission factors for feed mills associated with cattle feed yards. The goal of this study was to obtain more accurate emission factors for feed mills associated with feed yards that could be published with the new AP-42 (anticipated in January,1997) and used by SAPRAs to regulate air pollution attributed to animal feed mills.

Feed mills, like grain elevators incorporate simple grain handling systems. In the case of country elevators, grain is transported to the elevator, dumped into a pit, conveyed to the bucket elevator, elevated and conveyed to bins. The elevator shipping process involves emptying a bin, conveying grain to the elevator, elevating and loading onto rail cars. The profit of a grain elevator operation is dependent upon the volume of grain handled. Hence, most country elevators are designed to move grain from the unloading point to the bin rather quickly during the harvesting season. It is not unusual to have a 10,000 bushel per hour (300 tons/hr) leg at a elevator to minimize the waiting time of grain trucks transporting grain from the field to the elevator.

In contrast, a feed mill associated with a feed yard has a primary function of providing feed for the cattle in the yard. Grain storage is limited and the speed of unloading truckloads of grain is not as critical. Unlike a country elevator, the feed mill has an additional processing step in which the grain is processed into feed. This process typically includes steam flaking grain and mixing with other ingredients. A feed mill will process grain at rates of 15 to 100 tons/hr whereas a typical country elevator will move grain at rates of 300 to 500 tons /hr. A feed mill associated with a cattle feed yard must supply sufficient feed to meet the demand of the cattle in the yard every day whereas country elevators are seasonal industries. The annual hours of operation of elevators can be less than 1,000 per season whereas feed mills may operate in excess of 5,000 hours per year. The feed loading operation at a feed mill involves the batch loading of feed (at 20% moisture content or higher) into a feed truck. Clam shells can transfer 20 tons of feed to a truck in less than 3 minutes. The high moisture feed transfer results in very little dust entrained in air.

In summary the differences between a country grain elevator and a feed mill that potentially could impact emission factors are as follows:

- The profit made by a grain elevator is directly proportional to the volume of grain handled. A typical country elevator will handle approximately 300 tons/hr (10,000 bushels/hr). The primary function of a feed mill is to supply sufficient feed each day for the number of cattle on the yard. A feed mill associated with a 20,000 head feed yard operating for 14 hr/day will have a processing rate of approximately 20 tons/hr.
- A grain elevator is a seasonal industry which may operate 1,000 hours per year or less, whereas, a feed mill associated with a 20,000 head feed yard may operate 14 hours per day for approximately 5000 hr/year. Hence, the average particulate emission rate per unit time will be significantly higher for grain elevators versus feed mills.
- Due to the seasonal nature of operations at elevators, the grain receiving pits and legs have a larger capacity than those at feed mills. It is typical for the pit at a feed mill to fill up so that the grain backs up to the bottom of the truck. This is referred to as choke flow during which very little dust is entrained in air. Since it takes longer to get to choke flow at a dump pit with a larger capacity, it is likely that the unloading operation at country elevators do not encounter choke flow. The dust emission rate for grain receiving operations at a feed mill will likely be lower than those at grain elevators.

- The shipping/loading of grain from an elevator is a semi-continuous process through spouts, whereas, trucks are loaded in a relatively short period of time with clam shells and intermittently throughout the feeding cycle at feed mills.
- High moisture feed loaded onto trucks at a feed mill will have a significantly lower "free" dust content than dry grain loaded into rail cars. The emission factor for feed loading at a feed mill will be less than the emission factor for grain shipping at an elevator.

The definition of air pollution can be stated as: "Air pollution is the presence in the outdoor atmosphere of any one or more substances or pollutants in quantities which are or may be harmful or injurious to human health or welfare, animal or plant life, or unreasonably interfere with the enjoyment of life or property, including outdoor recreation" (Cooper & Alley, 1994). The role of air pollution regulations is to protect the public (off site). Regulating air pollution includes three functions; (1) formulation of rules and standards: which establishes the criteria for enforcement; (2) permitting: which establishes the controls required for a facility to be in compliance with the rules and regulations; and (3) enforcement: which establishes the types of punishment for violators. Enforcement is dependent upon rules, regulations and permitting. SAPRAs typically use the EPA emission factors in determining the maximum allowable emission rate. Hence, there is a need to be as accurate as possible in establishing emission factors for any emitting source.

There are two operations at a country elevator/feed mill that would logically result in particulate matter being entrained in air that could potentially result in air pollution. These are the transfer of grain from the truck to the elevator/mill (receiving or unloading) and the transfer of grain or feed from the elevator/mill to the truck (shipping or loading). The EPA AP-42 emission factors (Table 1) for unloading grain at grain elevators and feed mills were 0.6 and 2.5 lbs/ton, respectively (EPA, 1988). These factors were in error. The errors were a result of flawed methodology used by researchers to establish grain elevator emission factors.

An example of the problems encountered as a consequence of the 1988 AP-42 emission factors is illustrated by the following: The Oklahoma Department of Environmental Quality (DEQ) was in the process of using the 1988 AP-42 emission factors to regulate grain elevators and imposing TITLE V fees based upon TSP emission rates in 1994. At the request of the Oklahoma Grain and Feed Association, Parnell (1994a) testified to the Oklahoma DEQ pointing out the errors in AP-42. The impact in Oklahoma of their SAPRA using this approach to regulate grain elevators would have been a major source designation for many of the 300 plus elevators and an associated requirement for these elevators to obtain a Federal Operating Permit and pay TITLE V emission fees.

A grain dust emission study was conducted by Kenkel and Noyes (1995) as a result of the controversy. They measured the emission rates associated with the unloading and shipping operations of a country elevator and calculated the respective emission factors. Their protocol was approved by the Oklahoma DEQ. It involved unloading/loading a known amount of grain from and to a truck in a modified enclosed dump shed. A centrifugal blower was used to evacuate the dust laden air from the shed through an exhaust pipe. The exhaust air was passed through a set of fabric bag filters. The net mass of airborne dust was determined by the differences of the pre- and post weights of the filters. The sampling air generated by the centrifugal blower helped to keep the airborne particles in suspension until they reached the sampling pipe positioned near the center of the dump shed. Additional propeller fans were operated inside the shed to minimize particulate settling. In addition to capturing airborne dust, the mass of dust settled on the floor of the dump shed was also measured. To be conservative, the emission factor results from this study for grain elevator unloading and shipping operations were calculated by adding the mass that settled minus typical housekeeping that had settled to the floor to the airborne dust collected. Their results are summarized in **Table 4**.

Table 4: Emission Factors Proposed by Kenkel & Noyes (1995)

Operation	Airborne lbs/ton (A)	Floor Dust lbs/ton (B)	Housekeeping Adjustment lbs/ton (C)	Proposed Emission Factors lbs/ton (A+B-C)
Receiving-Hopper Bottom	0.019	0.034	0.015	0.038
Receiving-End Dump	0.039	0.049	0.021	0.067
Receiving Overall	0.029	0.042	0.018	0.053
Load-out	0.008	0.004	0.002	0.011

To add the mass of particulate that had settled to the floor prior to calculating emission factors is very conservative. In reality, any particulate that settles out prior to crossing the property line is not subject to air pollution regulations. The average emission factors based only on airborne dust measurements **(Table 5)** suggest that the hopper bottom unloading operation which corresponds to the typical grain unloading operation at animal feed yards was 0.019 lbs/ton.

Table 5: Average and Standard Deviations of Emission Factors Based on Air Sampling (Kenkel & Noyes,1995)

Emission Factor	Grain Receiving lbs/ton			Grain Load-Out
	Hopper Bottom	End-Dump	Overall	lbs/ton
Average	0.0191	0.0388	0.0290	0.0084
Std. Dev.	0.0016	0.0093	---	0.0025
	0.0207	0.0481		

Ideally, an accurate emission factor for feed mills should be one that represents the average emission rate of particulate matter from the facility. However, the permitted Allowable Emission Rate (AER) for a facility is typically calculated by SAPRA engineers by multiplying the emission factor by the rated capacity of the mill. AERs are used by SAPRAs to establish the maximum allowable emission rates of mills. Our goals for this research are to recommend emission factors that will allow a mill to operate in compliance with the SAPRA rules and regulations and to have these emission factors published by EPA. If the published emission factors were too low, it is possible that the AER of the mill would be too low and the mill will be subject to enforcement for non-compliance. The penalties for non-compliance can exceed $10,000 per day. Hence, our goal will be to determine an accurate average emission rate and to recommend an emission factor that is adjusted to account for the possibility of high dust levels in grain in some years. Our recommended emission factor should be higher than the average to insure that the AER determined by the SAPRA engineer is reasonable.

Objectives

The objectives of this feed mill emission factor study were:

- To measure the TSP emission rates resulting from grain unloading and feed loading operations;
- To calculate accurate TSP and PM-10 emission factors for grain unloading and feed loading operations; and
- To propose new emission factors for grain unloading and feed loading operations.

AIR POLLUTION/FEED MILLS

There are two operations at a feed mill that result in particulate matter being entrained in air that could potentially result in air pollution. These are the transfer of grain from the truck to the mill (receiving or unloading) and the transfer of feed from the mill to the truck (shipping or loading).

Grain Receiving Operation

The typical dimensions of an unloading shed are: length=30 ft; width=15 ft; height=15 ft. The typical dimensions of the entrance and exit of the shed are 12x14 ft. The dump pit is usually located at the center of the shed with typical dimensions of 8x12 ft. In a typical grain unloading operation at a feed mill, grain from the truck falls into the dump pit displacing an equal volume of air in the pit. The displaced air rises from the pit. The displaced air rising against the flow of grain results in particulate matter entrainment which can move out of the shed with the ambient air. The highest concentration of entrained dust occurs with the initial free falling grain when the rate of displacement is highest and the drop distance of the grain is highest (**Figure 1**). As the pit fills with grain, the grain rises to the truck, resulting in choke flow with little dust being entrained in the air (**Figure 2**). At choke flow, no air is being displaced by the falling grain. This results in a lower concentration of entrained dust. Typically, a truck contains 1,000 bushels of grain in two 500 bushel hoppers. It is common for the grain unloading operation to require 15 to 20 minutes to unload the 1,000 bushels including the time required to move the truck to align the second chamber over the pit. It is common for choke flow to occur within the first 3 minutes of unloading and continue throughout the unloading process.

Feed Loading Operation

The typical dimensions of a feed loading shed are: length=30 ft; width=15 ft; height=15 ft. Typical dimensions of the entrance and exit of a shed are 12x14 ft. The clam shell is located on the ceiling of the loading shed, as shown in (**Figure 3**). Some feed mills have more than one clam shell; in which case, the feed loading shed is proportionately longer.

The feed loading operation at a feed mill is relatively simple and short compared to the grain unloading operation at a country elevator. The feed is conveyed into the clam shell from the storage bins using mechanical conveyors. It is loaded on a feed truck by opening the clam shell. The feed falls into the truck positioned underneath the clam shell, as shown in (**Figure 4**). The opening of the clam shell and dumping of the feed into a feed truck takes anywhere from 10 seconds to one minute to load 3 to 16 tons. Dust is entrained in the air when the feed drops into the truck. Due to the high moisture content of the feed, low free dust content of the feed, and the short duration of the operation, very little dust is entrained in the air in this operation.

Figure 1: Grain Unloading Operation
(before choke flow)

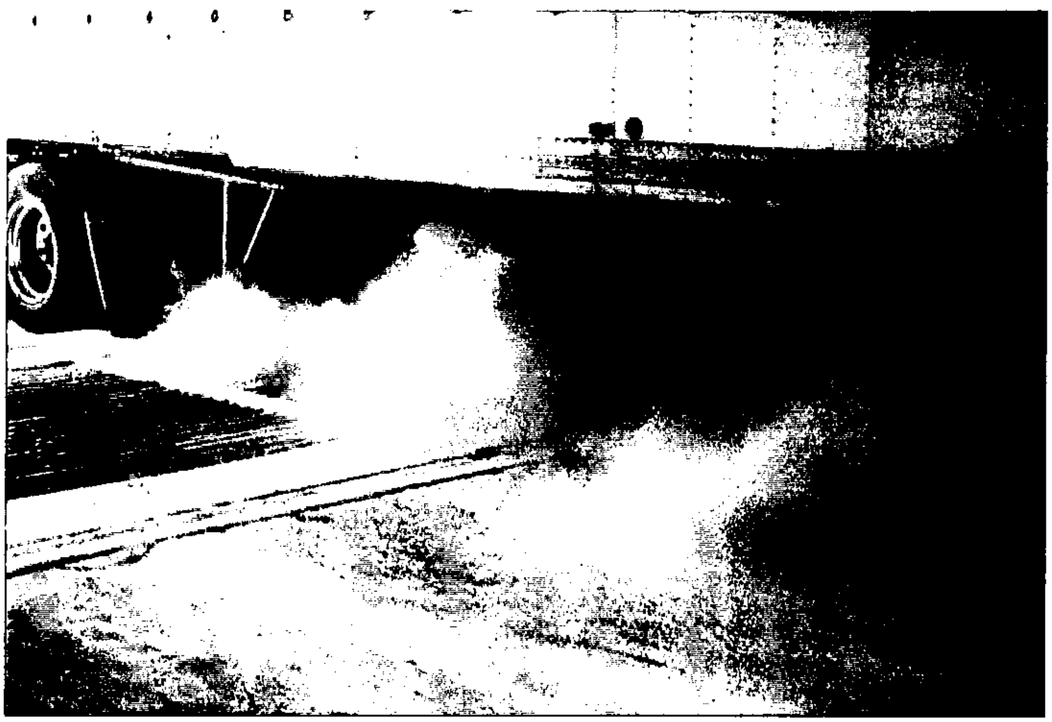


Figure 2: Grain Unloading Operation
(during choke flow)

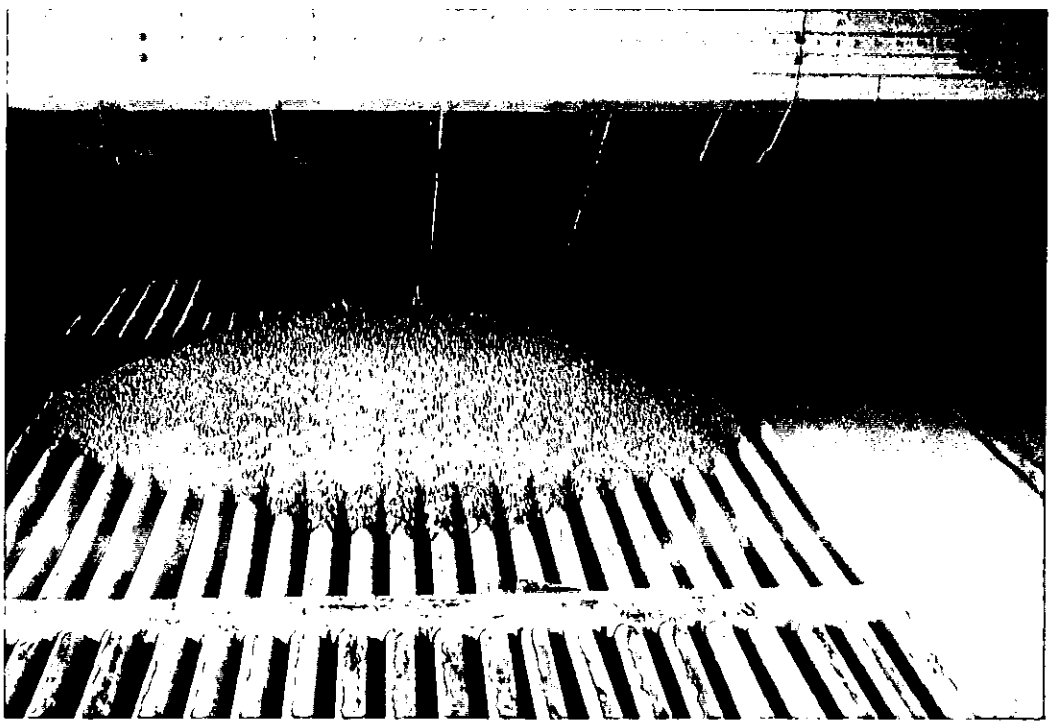


Figure 3: Clam Shell

Figure 4: Loading Feed into a Truck at Mill B
With a Clam Shell

Selection of Feed Mills

The feed mill selection process was based on the following criteria:

(1) We desired results from our study to be representative of all sizes of feed yards in the United States. A preliminary survey of the feed yards across the United States indicated that feed yards in Nebraska were predominantly small with less than 20,000 head per yard. Many of the feed yards in Texas were medium size with capacities of 20,000 to 40,000 head. Some large feed yards were located in Kansas. We selected a small, medium and large feed yard in Nebraska, Texas and Kansas, respectively for this study.

(2) In order to facilitate the grid sampling protocol, we attempted to select mills where the grain unloading and feed loading sheds were aligned with the prevailing wind direction; We attempted to select mills in each state having their sheds aligned with the prevailing wind direction.

(3) It was essential that we obtain full cooperation of the mill manager. A cooperative attitude of the mill management was a criteria utilized.

(4) An initial site was selected to test our protocols, sampling equipment, and procedures. Feed mill A located in Texas was selected because of its close proximity to Texas A&M University. Our purpose for sampling at this feed mill was to insure that our equipment and sampling procedures would result in quality data from mills B, C and D. We made several improvements in procedures and equipment following the sampling at feed mill A. The data collected from this mill were not used.

Description of Feed Mills

Feed Mill A

The general layout of the feed mill is shown in (**Figure 5**).

- capacity of feed yard: 12,000 head
- number of feed mill operating hours in a day: 16
- dimensions of grain receiving dump pit: 8.5x11 ft
- capacity of dump pit: 400 bushels
- capacity of grain receiving leg: 3000 bushel/hr
- dimensions of entrance and exit to grain receiving shed: 14x14 ft
- processing rate of feed mill: 10-15 tons/hr

Feed Mill B

The general layout of the feed mill is shown in (**Figure 6**).

- capacity of feed yard: 12,000 head
- number of feed mill operating hours in a day: 12
- dimensions of grain receiving dump pit: 3x12
- capacity of dump pit: 600 bushels
- capacity of grain receiving leg: 4500 bushel/hr
- dimensions of entrance and exit to grain receiving shed: 12x14 ft
- dimensions of feed loading clam shell: 7.5x14 ft
- dimensions of entrance and exit to feed loading shed: 12x14 ft

Figure 5: General Layout Diagram
Mill A

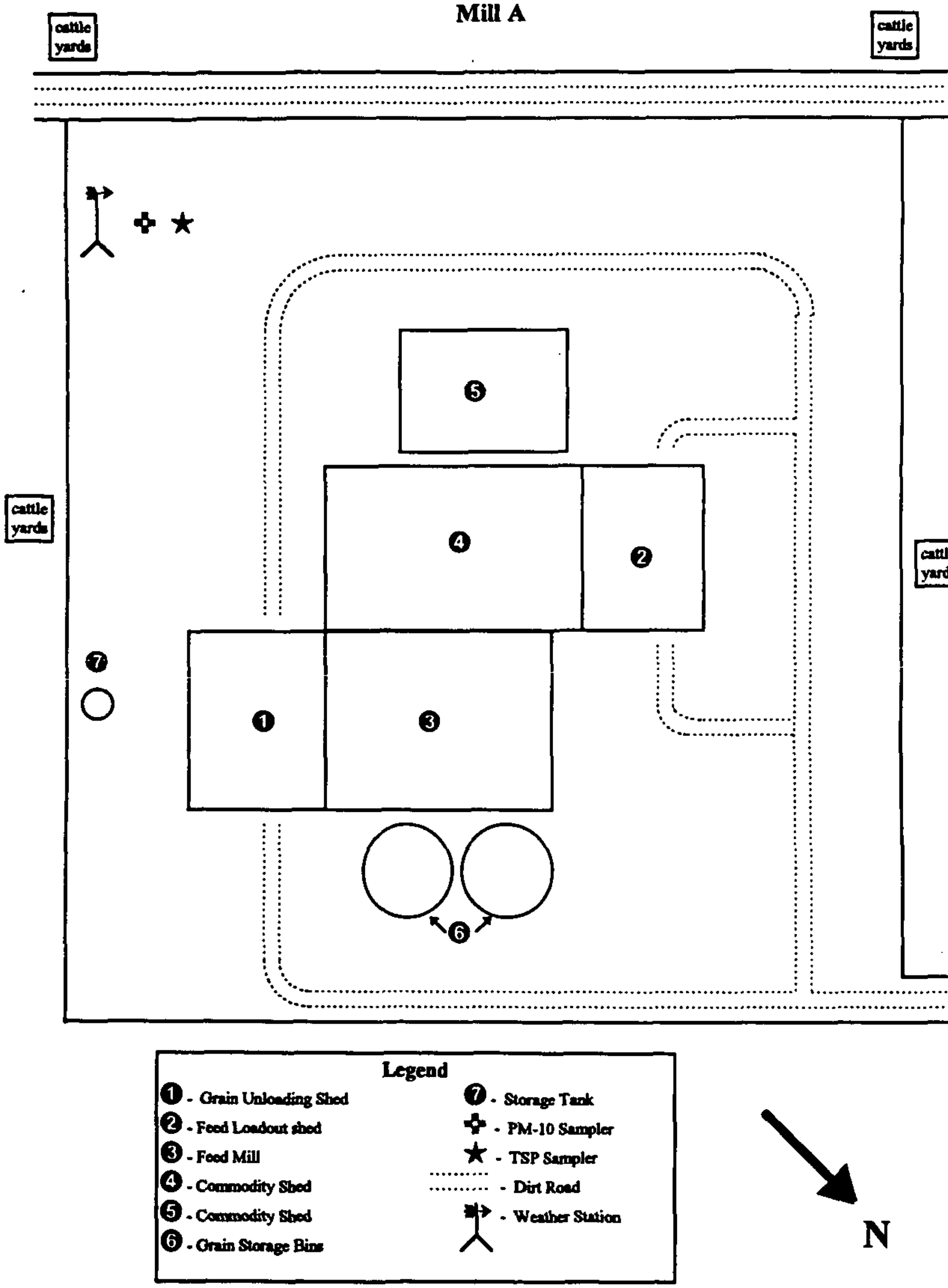
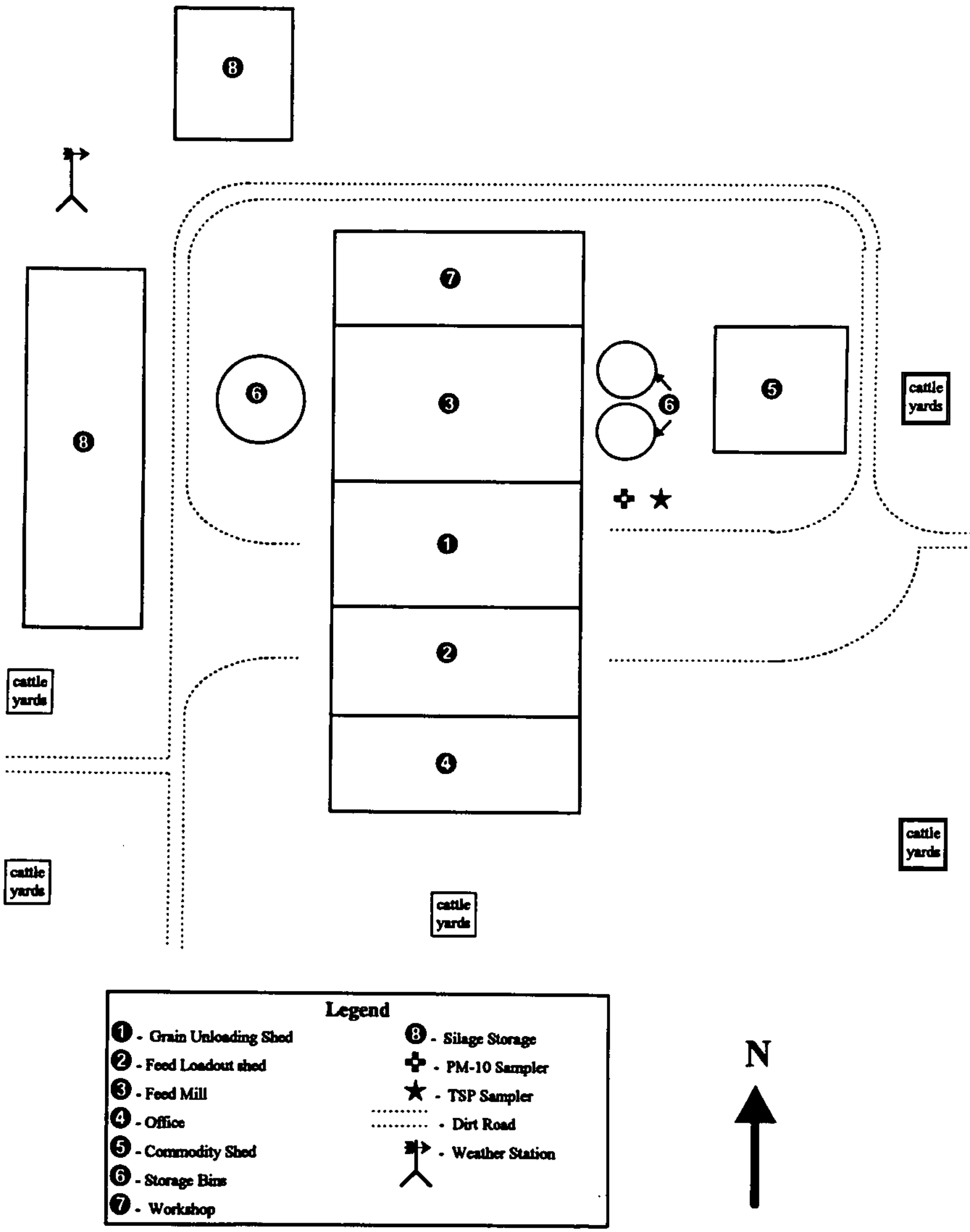


Figure 6: General Layout Diagram
Mill B



- processing rate of feed mill: 10-15 tons/hr
- feed mixed before loading on feed trucks: partially (The trucks at this mill were mixing trucks i. e. the feed was mixed as the truck delivered the feed.)

Feed Mill C

The general layout of the feed mill is shown in (Figure 7).

- capacity of feed yard: 110,000 head
- number of feed mill operating hours in a day: 24
- dimensions of grain receiving dump pit: 8.5x12 ft
- capacity of dump pit: 400 bushels (This mill had three pits. We only sampled from the pit with a capacity of 400 bushels.)
- capacity of grain receiving leg: 4000 to 6000 bushel/hr
- dimensions of entrance and exit to grain receiving shed: 12x14 ft
- dimensions of feed loading clam shell: 12x13 ft
- dimensions of entrance and exit to feed loading shed: 12x12 ft
- processing rate of feed mill: 60-80 tons/hr
- feed mixed before loading on feed trucks: Yes

Feed Mill D

The general layout of the feed mill is shown in (Figure 8).

- capacity of feed yard: 20,000 head (This mill was not at capacity because of the drought while we were sampling.)
- number of feed mill operating hours in a day: 12
- dimensions of grain receiving dump pit: 9.5x12 ft
- capacity of dump pit: 400 bushels
- capacity of grain receiving leg: 3000 to 4000 bushel/hr
- dimensions of entrance and exit to grain receiving shed: 12x16 ft
- dimensions of feed loading clam shell: 5x8 ft
- dimensions of entrance and exit to feed loading shed: 12x14 ft
- processing rate of feed mill: 15-20 tons/hr
- feed mixed before loading on feed trucks: Yes

Figure 7: General Layout Diagram
Mill C

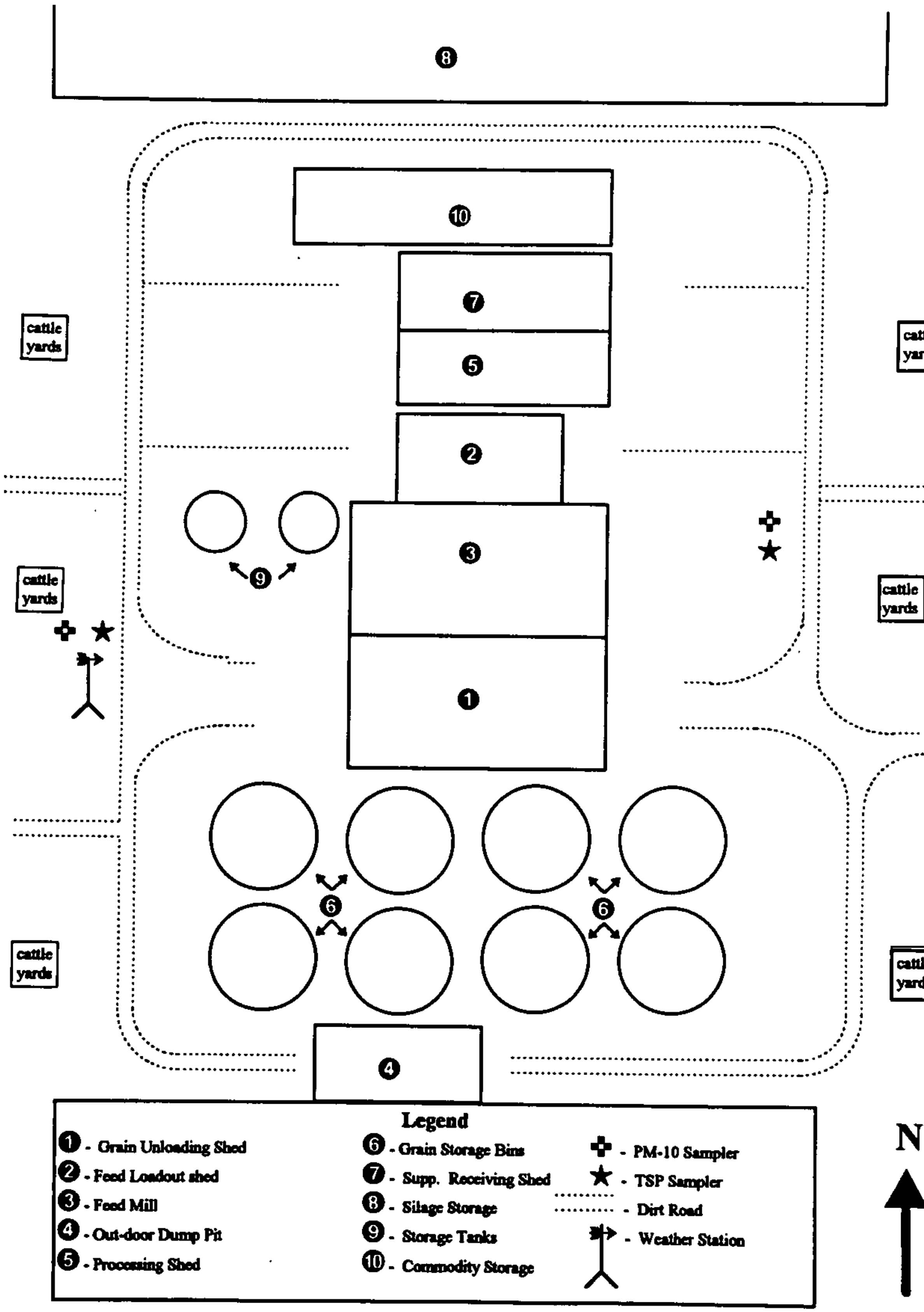
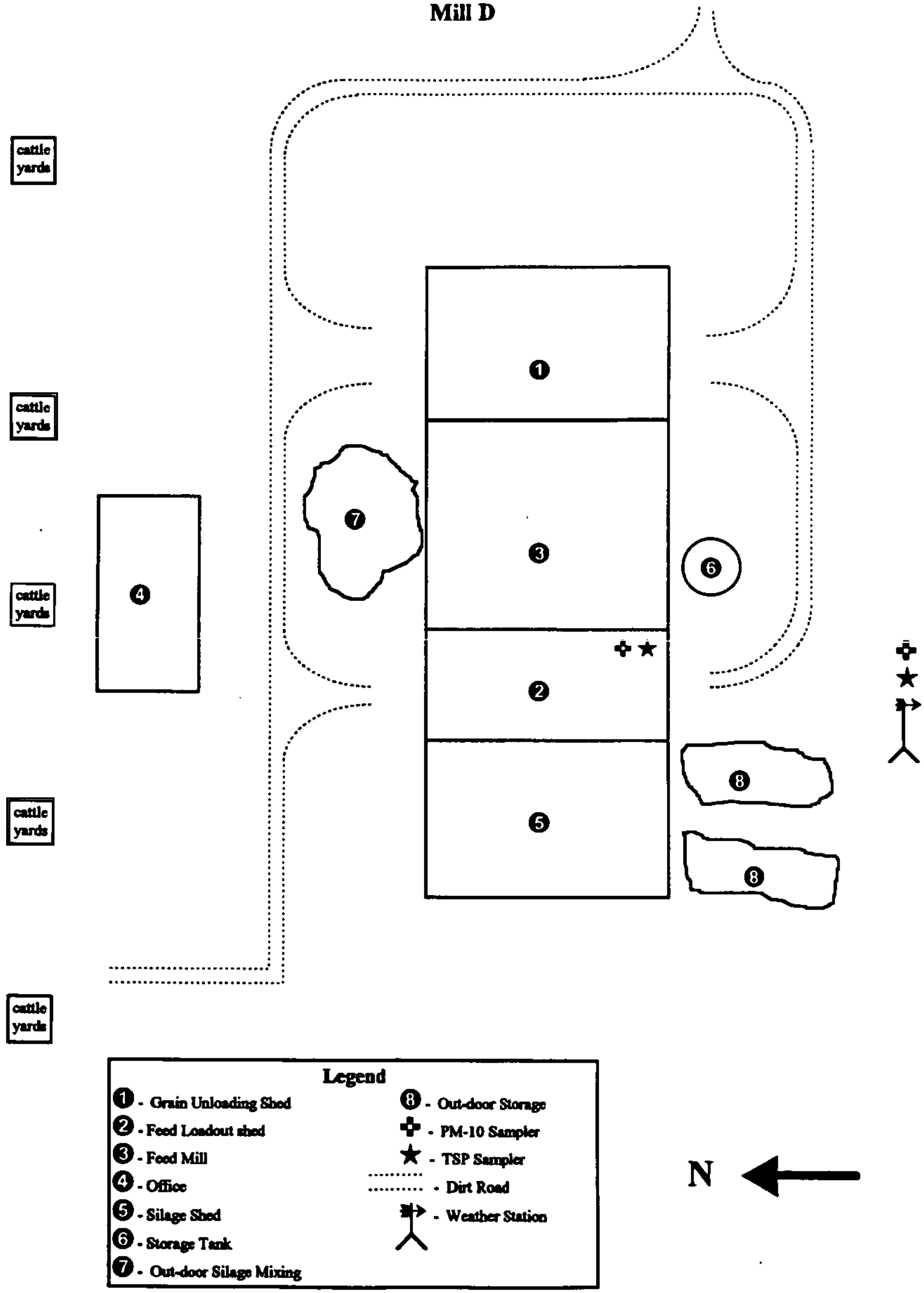


Figure 8: General Layout Diagram
Mill D



SAMPLING PROCEDURES

We designed and engineered two sampling procedures in an attempt to obtain accurate measurements of the TSP emission rate resulting from the grain receiving operations at a feed mill. One protocol utilized a plastic enclosure underneath the truck to contain the dust entrained in the air. (This procedure is similar to the protocol used by Kenkel & Noyes (1995)). The enclosure prevented the dust from moving out of the shed with the ambient air and facilitated the capture of dust with four high volume samplers. We referred to this protocol as "under the truck" sampling. It was anticipated that the results using the "under the truck" protocol would provide the most accurate measurements of the grain unloading emission factor in that all dust entrained in the air during an unloading operation would be captured. The emission factor calculation would consist of dividing the total dust captured by the total mass of grain unloaded. We planned to use this same procedure for feed loading, but we were only able to use the "over the truck" protocol at Feed Mill A because of the physical constraints of the other unloading sheds. We referred to this protocol as "over the truck" sampling.

The second procedure consisted of measuring the concentration of particulate at three different heights at the downwind exit of the shed. The particulate mass emission rate consisted of measuring the net average concentration at the downwind exit of the shed and multiplying this number by the average volumetric flow rate of air through the shed during the unloading (grain) and loading (feed) periods. The ratio of the net mass of particulate leaving the shed and the tons of grain unloaded or feed loaded yielded an emission factor. We referred to this protocol as "grid sampling".

"Under the Truck" Sampling
To prepare for sampling underneath the truck, we enclosed the dump pit (8x10 ft) along its perimeter with a continuous plastic sheet 6 ft wide. The plastic was stapled to sections of 2x2 inch wood on all four sides of the pit for anchoring purposes. The sides of the enclosure were laid down flat over the dump pit before the grain truck was driven into the shed as shown in (**Figure 9**).

Once the truck was positioned over the dump pit, the plastic was lifted up to the sides of the truck (as shown in **Figures 10, 11 & 12**) and clamped using numerous metal clips on all four sides of the hopper, thus enclosing the area underneath the hopper and above the dump pit. Four sampling probes, two on each side of the truck, were introduced into this plastic at a height of about 2.5 ft (as illustrated in **Figure 13**). Each sampling probe was connected to a cyclone pre-separator, specially designed for this study (shown in **Figure 14**). A pre-weighed zip-lock bag was attached to the bottom of the cyclone pre-separator to collect the particulate separated from the air stream by the cyclone. The particulate penetrating the cyclone was captured by an 8x10 inch filter. It was our goal to be able to sample one truck without having to change the

Figure 9: Plastic Enclosure Setup at Grain Receiving Pit

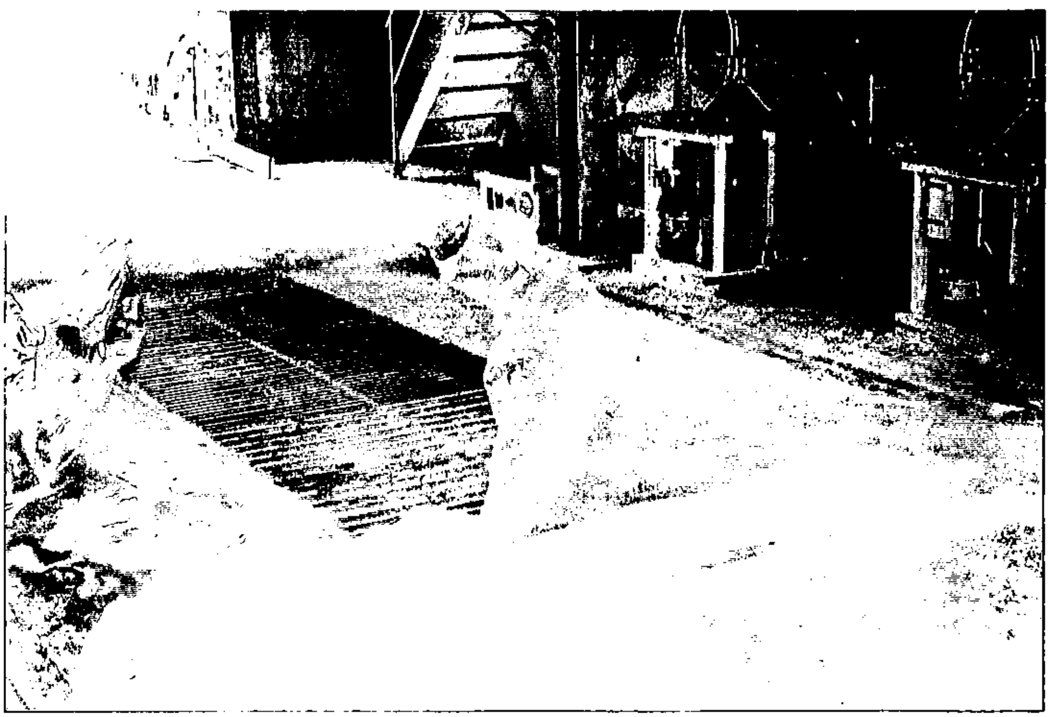


Figure 10: Attaching the Plastic Enclosure to the Grain Truck

Figure 11: Two Sampling Points Introduced Inside the Plastic Enclosure on Each Side of the Grain Truck

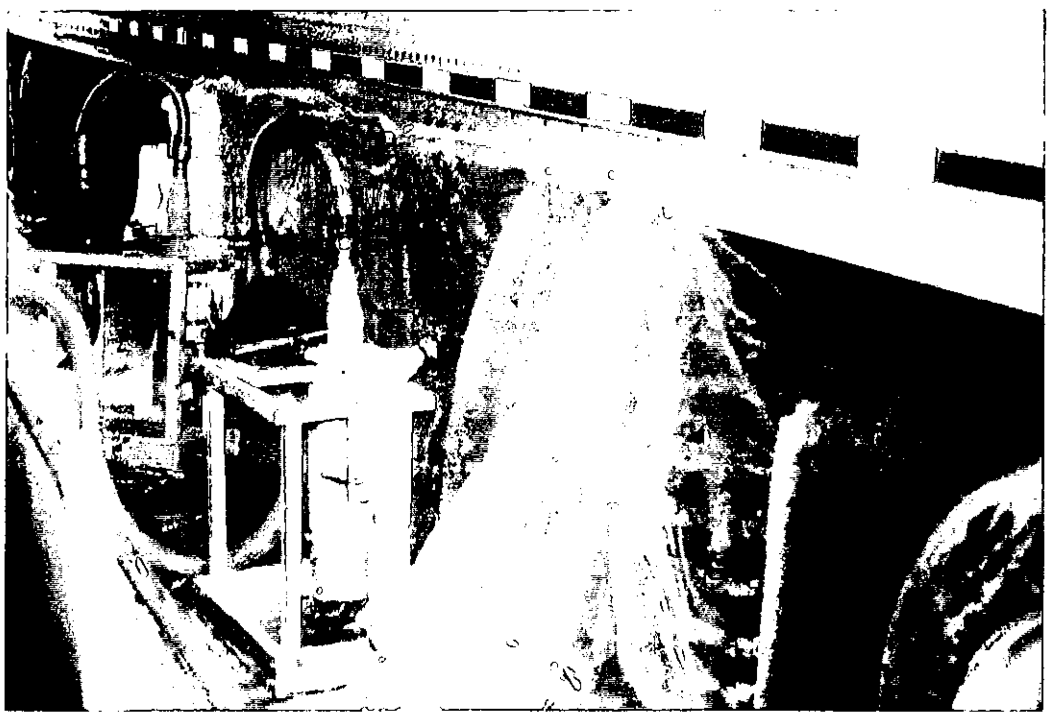


Figure 12: Under Truck Sampling at the Grain Receiving Dump Pit

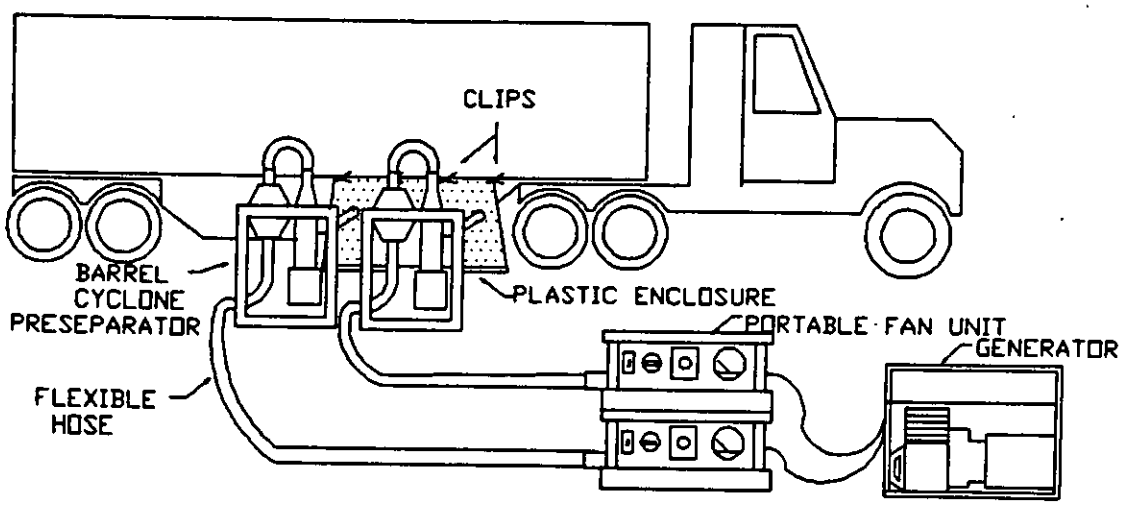


Figure 13: Plastic Enclosure Around Grain Receiving Dump Pit

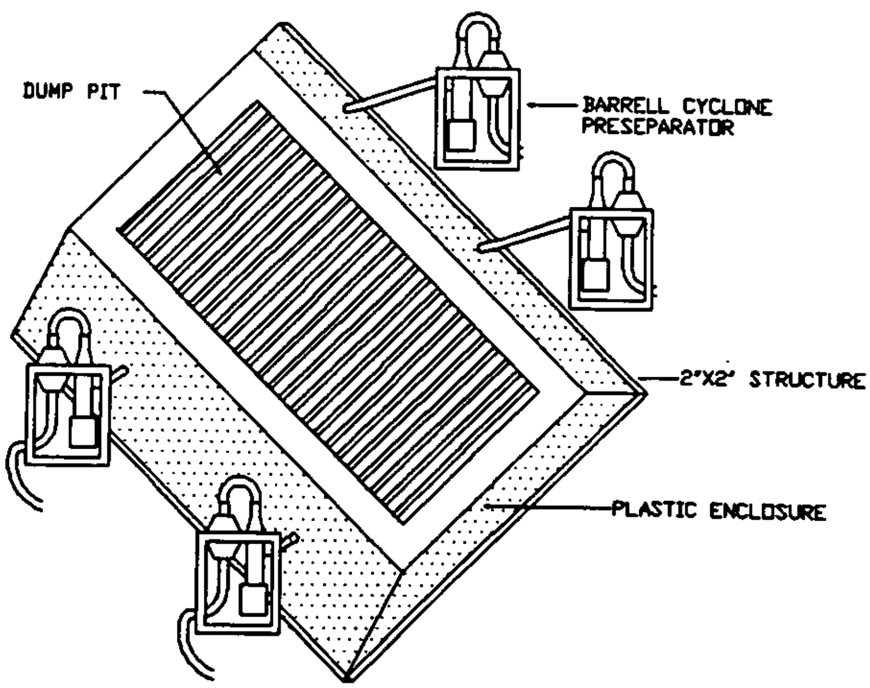
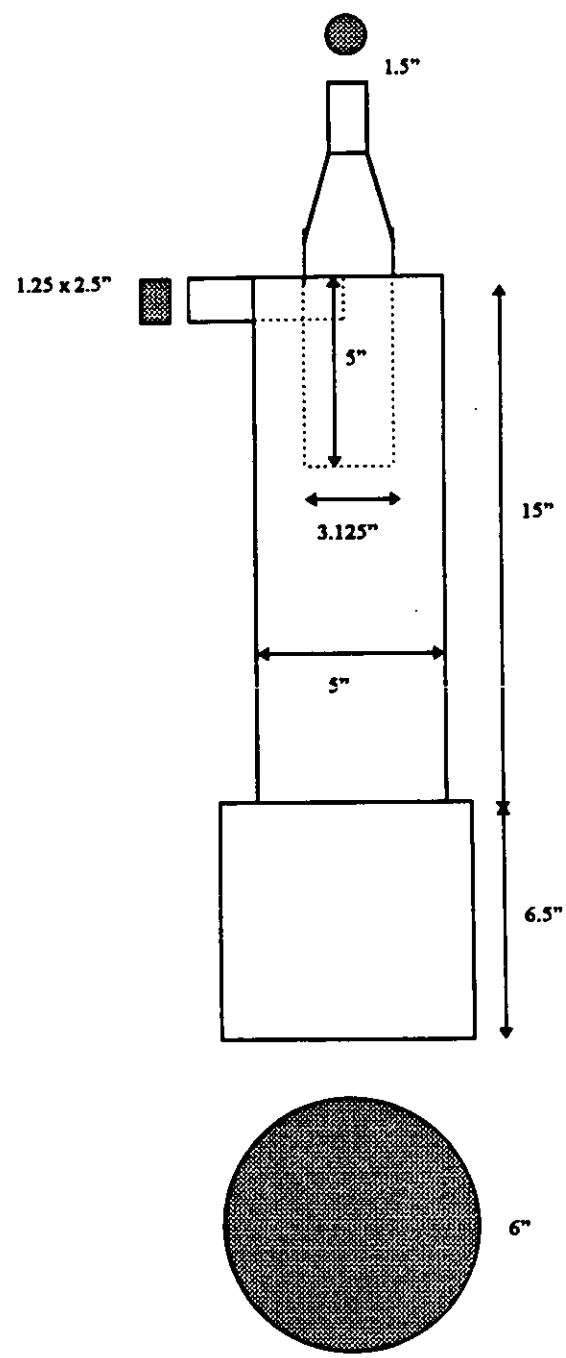


Figure 14: Cyclone Pre-Separator Design



8x10 inch filters during the sampling of each truck. Based on the interim emission factor of 0.15 pounds of dust per ton of grain, each sampler was required to capture one pound of particulate. Laboratory tests established the efficiency of the cyclone pre-separator to be 99.8% for corn dust. The maximum filter loading was determined to be approximately 2 gm. The results of tests conducted in the lab (Appendix C) prior to the sampling trip indicated that this sampling system could capture up to one pound of particulate while maintaining 52 cfm throughout the sampling period.

A centrifugal flow fan was used to pull air through this system. The volume rate of flow (sampling rate) through the system was measured using a calibrated orifice meter and controlled with a variable AC voltage supply (variac) connected to the fan. The control panel consisted of a main switch, a digital timer, a variac and a magnehelic gauge. The sampler system is shown in (**Figure 15**). The samplers were turned on when the unloading operation was initiated; turned off when the truck driver had completed unloading the first hopper and was aligning the second hopper over the pit (no grain was being unloaded during this period) and turned on again during the period that the second 500 bushels were being unloaded. The sampling period consisted of the entire unloading period plus approximately one minute following the unloading operation in an attempt to fully capture all of the particulate entrained in the air. The volumetric flow rate through each sampler was adjusted and maintained at 52 cfm throughout the sampling period. The 52 cfm corresponded to the design velocity of the cyclone pre-separators. At the end of the sampling period, the run time for each sampler was recorded and the exposed filters and zip lock bags were collected, stored and subsequently returned to the lab for analyses . Unexposed, preweighed filters and zip-lock bags were placed on the samplers in preparation for the next sampling period.

"Over the Truck" Sampling
To sample over the truck, the clam shell (8x14 ft) was enclosed along its perimeter with a plastic sheet approximately 48 ft long and 6 ft wide. The plastic was clamped to the sides of the clam shell in a way that it would hang freely, thus enclosing the area underneath the clam shell and above the feed truck. Once the truck was positioned under the clam shell and our intentions explained to the truck driver, four sampling probes were inserted into this plastic enclosure at a height of approximately 13 ft. All of the samplers were located on one side of the truck due to physical constraints (as shown in **Figures 16 &17**). Each sampling probe was connected to a cyclone pre-separator, specially designed for this study (shown in **Figure 14**). A 12 ft. long, 1.5 inch diameter extension pipe was used to access the plastic enclosure above the truck. Zip lock bags were attached to the bottom of the cyclone pre-separator to collect the particulate separated from the air stream. The particulate penetrating the cyclone was captured by an 8x10 inch filter connected to the outlet of the cyclone. A centrifugal flow fan was used to pull air through this system. The volumetric flow rate of air through the system was controlled using a calibrated orifice meter and a variac. The control panel consisted of a main switch, a digital timer, a variac and a magnehelic gauge. The sampler system is shown in **Figure 15**. The samplers were turned on during the transfer of feed from the clam shell to the truck. The volumetric

Figure 15: Under the Truck Sampling System

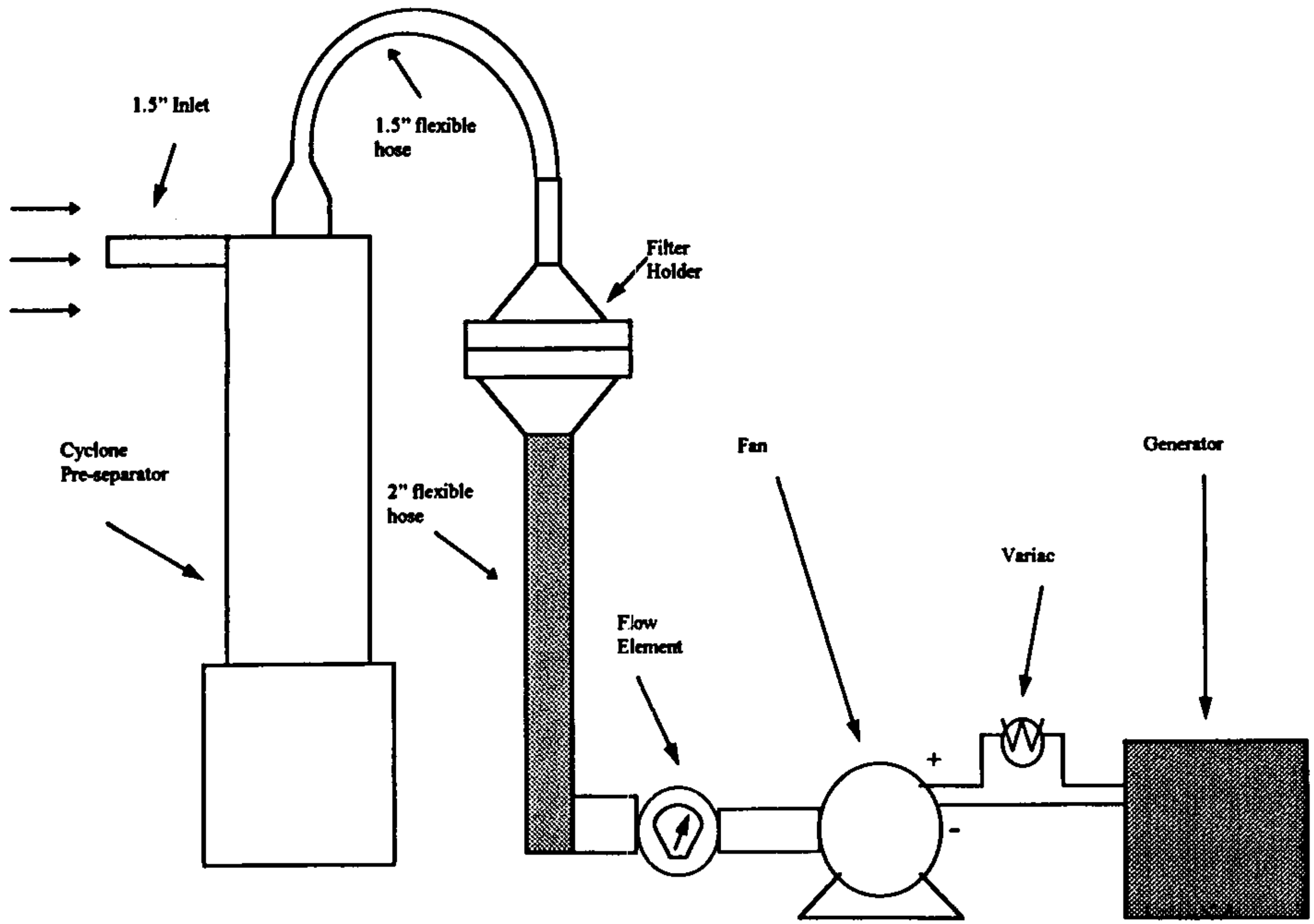
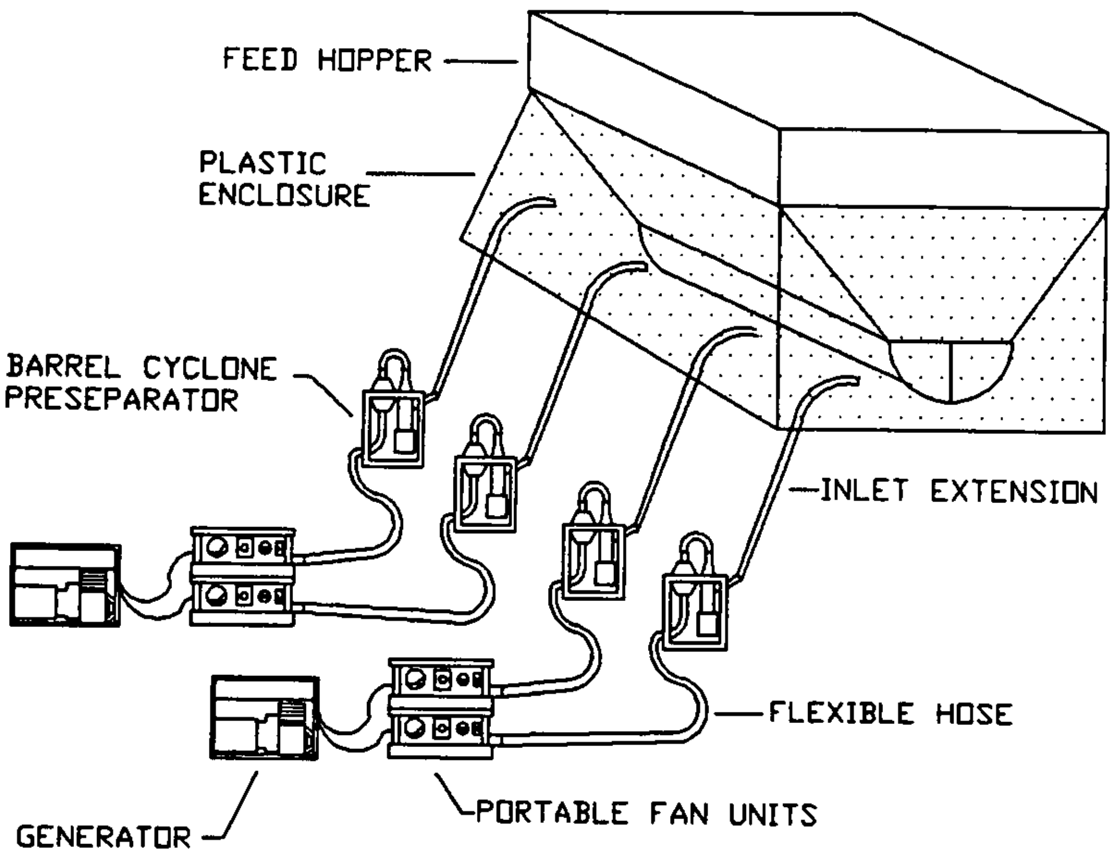


Figure 16: Sampling "Over the Truck" During Feed Loading Operation

Figure 17: Over Truck Sampling Setup at Feed Loading



flow rate of air through each sampler was adjusted and maintained at 52 cfm corresponding to the design velocity of the cyclone pre-separators, throughout the sampling period. The samplers were turned off after the truck had been loaded. After the truck left the shed, the sampling time for each sampler was recorded and the exposed filters and zip lock bags were exchanged for new ones for the next sampling period.

Grid Sampling

The grid sampling equipment consisted of two stands with three open faced 8x10 inch filters mounted on each stand at 3, 6 and 9 feet above the ground. Both stands (6 samplers) were placed at the downwind exit of the grain unloading shed, between the truck and the wall of the shed (one stand on each side of the truck). This is shown in (**Figures 18 & 19**). Air was pulled through each sampler using the same centrifugal fan and control panel designed for the "under the truck" sampling. Sampling was initiated at the start of the grain unloading operation. The volumetric air flow rate was adjusted and maintained at 40 cfm throughout the sampling period. The samplers were shut off during the short time period when the truck had unloaded the grain from the first hopper and was aligning the second hopper over the pit. The sampling period was completed when the grain unloading operation was completed. After the truck left the shed, the sampling times for each sampler were recorded and the exposed filters were collected and stored. New pre-weighed filters were loaded in preparation for the next sampling period.

At mill C, the grid sampling for feed loading was slightly modified. Due to safety concerns, one stand with three open faced sampling probes was used on each end of the feed loading shed and operated continuously. The time required to load feed into a feed truck was relatively short and the distance between the truck loading position and the exit and entrance of the shed allowed for the mixing of the entrained particulate.

The wind velocity inside the shed was periodically measured with a hot wire anemometer and recorded during the sampling period (Appendix I). A weather station was set up at each site to record wind velocity, wind direction, temperature, relative humidity and barometric pressure. High Volume (HiVol) and PM-10 (Wedding) samplers were used to measure the background TSP and PM-10 concentrations upwind at Nebraska and Texas and upwind and downwind at Kansas. **Figure 20** shows the setup of a weather station and the HiVol and a PM-10 samplers used to measure background concentrations (Appendix G).

Drop Tests

A drop test system was designed to determine the free dust content of grain, with the intentions of developing a relationship between the free dust content of grain and the emission factors for grain unloading and feed loading operations. The drop test chamber was a 3x3x3 ft metal chamber with a 5 ft long stack having a cross section of 1x1 ft. To simulate grain unloading and feed loading operations, each grain and

Figure 18: Grid Sampling

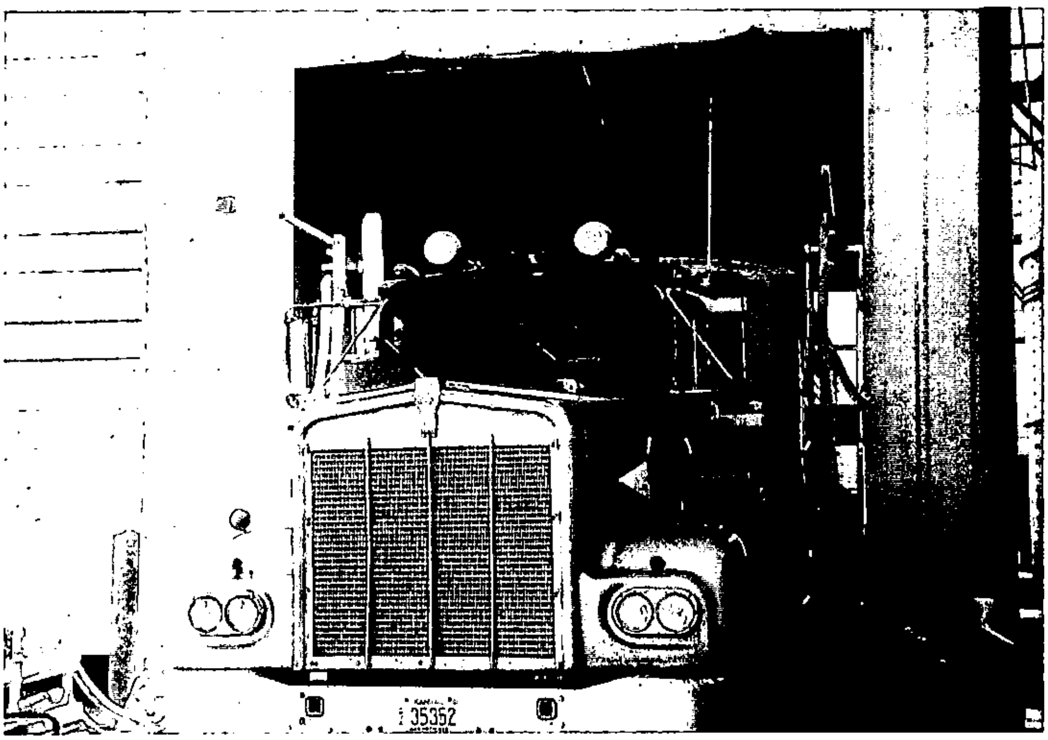


Figure 19: Grid Sampling Setup at Grain Receiving Shed

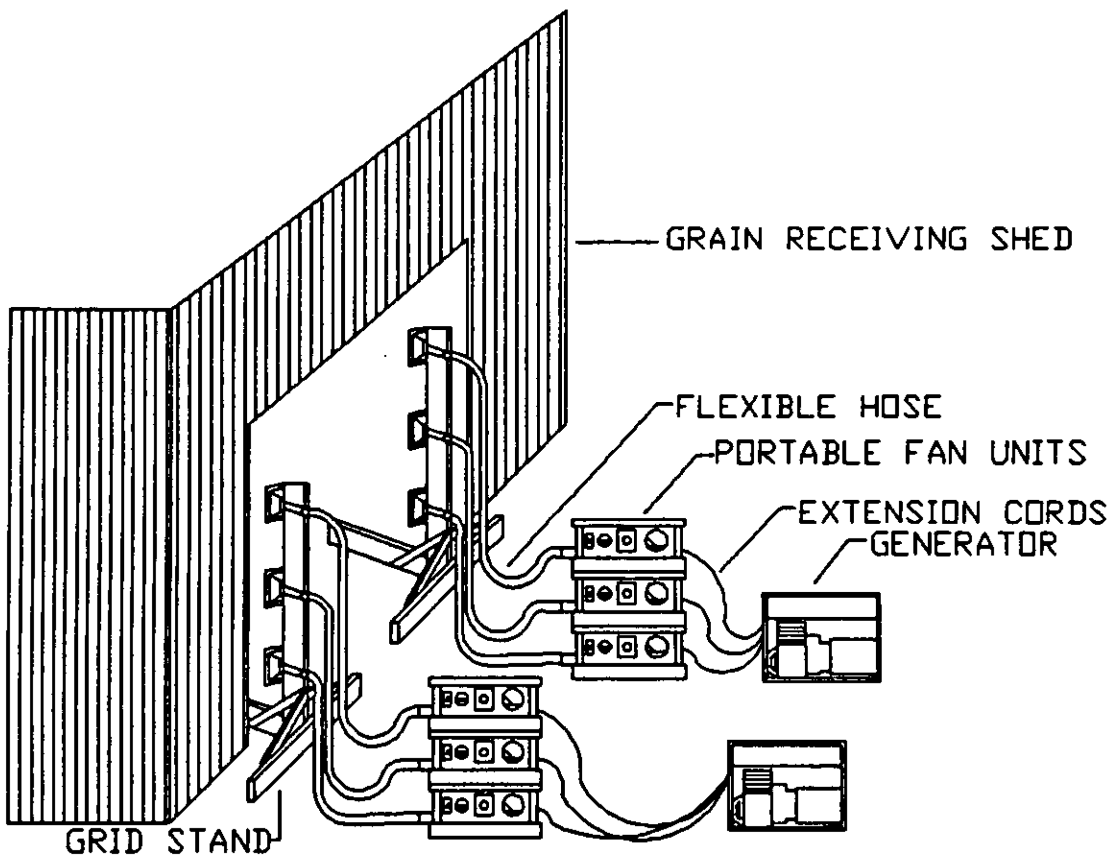
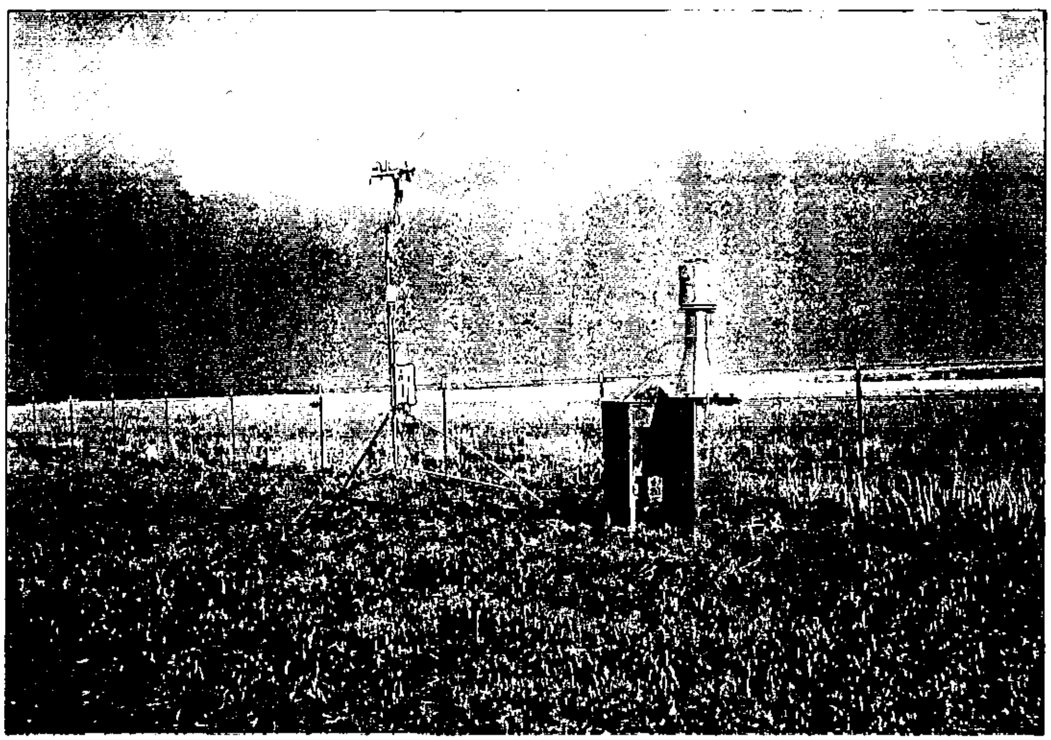


Figure 20: Weather Station and Background Samplers



feed sample was dropped approximately 8 ft to the bottom of the chamber. Dust contained in the grain or feed was entrained into the air inside the chamber. Air inside the chamber was drawn onto an 8x10 inch filter via a sampling probe introduced inside the wall of the drop test chamber. Air was pulled from inside the chamber at a rate of 75 cfm using a centrifugal fan and a control panel identical to those described previously. The sampling period for each drop test was 3 minutes resulting in approximately six air changes in the chamber. This ensured the capture of all the dust entrained in air as a consequence of the sample being dropped 8 feet and striking the floor of the chamber. The mass of each grain sample was 3 pounds. The feed samples had only small amounts of "free" dust. Hence, two 5 pound samples of feed were used for each drop test of feed. A minimum of 4 replications was performed on each load of grain and feed unloaded or loaded, respectively. A schematic diagram and a picture of the drop test is shown in **Figures 21 & 22**. Appendix F contains a detailed analyses of the design and performance testing of the drop testing system.

Particle Size Distributions

Particle size distribution analyses of particulate captured on all HiVol samplers and particulate captured by the preseparator cyclone were conducted using a Coulter Counter Multisizer in the Processing Laboratory, Department of Agricultural Engineering. These data were used to calculate PM-10 emission factors. Appendix C contains a detailed description of our Coulter Counter procedures.

Sampling Protocols

<u>Protocol (A): "Under the Truck" Sampling</u>

The following steps were taken to prepare for sampling using this protocol:

1. Measure and record the dimensions of the grain receiving shed, dump pit, etc.
2. Place plastic enclosure over the dump pit. Block off the area of the dump pit not enclosed, using extra sheets of plastic.
3. Position four sampling probes (inlet to the pre-separators), two on each side.
4. Install filter cassettes with lids and zip lock bags on each of the four samplers. Record the filter number and bag number being placed on each sampler.
5. Make sure the samplers are turned off and start generators.
6. Reset digital timer to zero.

The following steps were taken just prior to, during and upon completion of the sampling:

1. The safety coordinator obtained the truck driver's cooperation. All instructions and communication with the truck driver were the responsibility of the safety coordinator.
2. When the truck was positioned to unload grain from the first hopper, the top of the plastic enclosure was clipped to the bottom and sides of the truck forming a chamber above the pit to contain entrained dust.
3. Insert the inlets of the four samplers inside the enclosure through the plastic just inside and near the four corners of the plastic enclosure.

Figure 21: Drop Test Structure

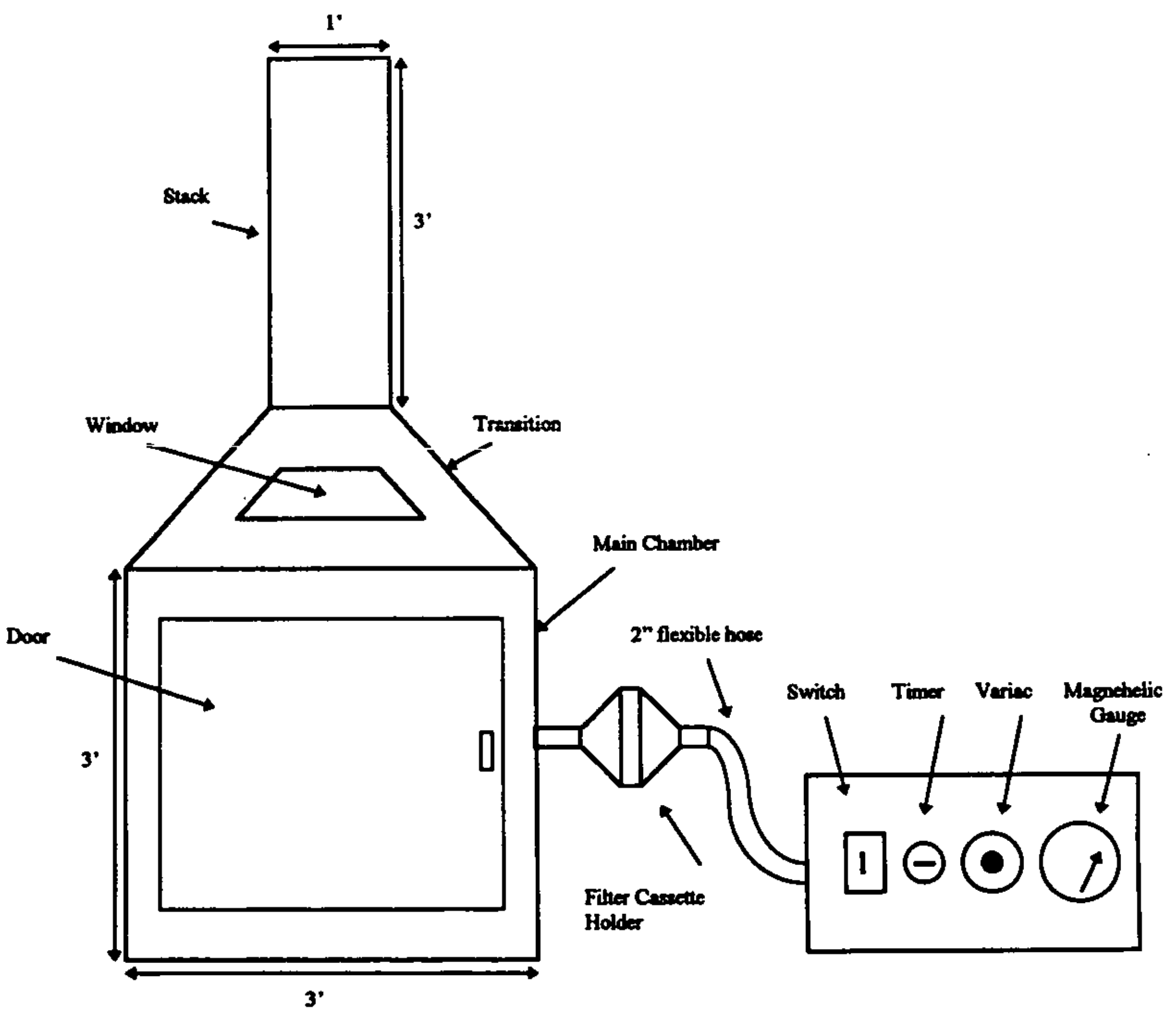
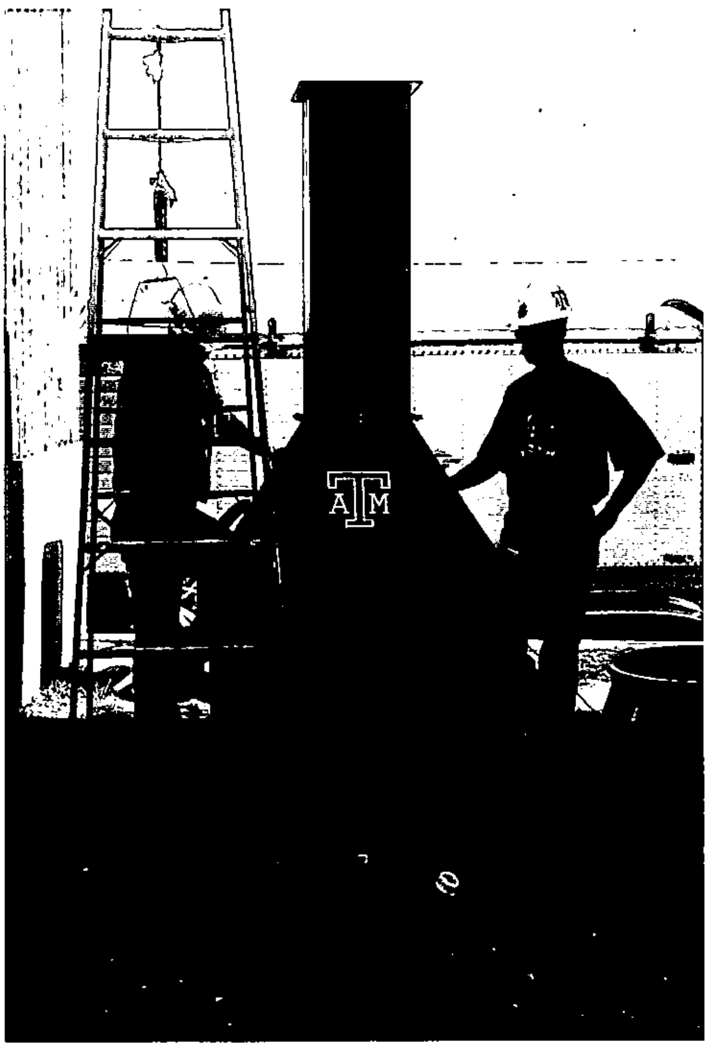


Figure 22: Drop Test Setup



4. Switch the samplers on as soon as the driver starts opening the first hopper. Adjust and maintain each sampler at a flow rate of 52 cfm throughout the sampling period. (We requested the drivers to open the hopper slowly so that grain unloading rate was less than 167 bushels per minute which is equivalent to 208 cfm.)
5. Switch the samplers off and pull the pre-separator units away from the plastic enclosure after the driver closed the first hopper.
6. Remove the clamps holding the plastic enclosure to the bottom and sides of the truck and let the truck move forward to align the second hopper over the pit.
7. Reattach the plastic enclosure to the truck and insert the sampling probes inside the plastic enclosure.
8. Switch the samplers on as soon as the driver starts opening the second hopper and maintain a flowrate of 52 cfm throughout the sampling period.
9. Switch the samplers off and pull the pre-separator units away from the plastic enclosure after the driver has closed the second hopper.
10. Remove the clamps holding the plastic enclosure to the truck and let the truck move out of the shed.
11. Record filter sampling times on data sheet.
12. Change filter cassettes and zip lock bags in preparation for the next truck.
13. Reset digital timers on each control unit.

<u>Protocol (B): "Under the Truck" Sampling</u>

A protocol similar to Protocol (A) was developed for cases where there was not enough room to place samplers on both sides of the truck in the grain receiving shed. This protocol was exactly the same as Protocol (A) except that instead of introducing two sampling probes on each side of the truck, all four sampling probes were introduced on one side.

<u>Protocol (C): Grid Sampling</u>

The following steps were taken to prepare for sampling:

1. Set up background samplers (one HiVol and one PM-10) just outside and upwind of the grain unloading shed.
2. Measure and record dimensions of the grain receiving shed, dump pit, etc.
3. Position right and left grid stands at their respective side of the downwind opening of the grain receiving shed and anchor them with sand bags.
4. Install filter cassettes with filter protection cover to each sampling probe and record the filter numbers that corresponded to each sampling probe.
5. Reset digital timers on each portable fan unit.

The following steps were taken just prior to, during and upon completion of the sampling period:

1. Remove filter protection covers.
2. Turn on the samplers simultaneously approximately 10 seconds prior to the opening of the first hopper to allow the portable fan units to reach the desired sampling rate.

3. Adjust and maintain each sampler at a volumetric flow rate of 40 cfm throughout the sampling period.
4. Take measurements of the grain truck at the exit of the grain receiving shed for the calculation of the exit area.
5. Measure and record air velocity measurements on each side of the grain truck using a hot wire anemometer. Check for variations in wind speed versus vertical height and record results.
6. Turn the samplers off after the driver has closed the first hopper and while the grain truck is moved forward to unload the second hopper.
7. Turn the samplers on simultaneously approximately 10 seconds prior to the opening of the second hopper to allow the portable fan units to reach the desired sampling rate.
8. Adjust and maintain each sampler at 40 cfm throughout the sampling period.
9. Measure and record air velocity measurements on each side of the grain truck using a hot wire anemometer. Check for variations in wind speed versus vertical height and record results.
10. Turn the samplers off after the driver has closed the second hopper.
11. Record sampling times on data sheet.
12. Replace filter protection covers and change cassettes in preparation for the next truck.
13. Reset the digital timers.
14. Change background filter cassettes every three hours.

<u>Protocol (D): Grid Sampling</u>

Protocol D is similar to Protocol (C). It was developed for cases where there was not enough space at the entrance or exit of the grain receiving shed to place the background samplers. This protocol is exactly the same as Protocol (C) except that the background samplers were placed approximately 20 meters away from the shed on the upwind side.

<u>Protocol (E): "Under the Truck" Sampling/Grid Sampling</u>

A separate protocol was developed to sample under the truck with the plastic enclosure and at the same time sample with the grid. This protocol was a combination of Protocols (A) & (C). It was only used at feed mill B to estimate the mass of particulate that escaped the plastic enclosure.

<u>Protocol (F): Drop Test</u>

The following steps were used to conduct the drop tests at each mill:

1. Fill one or two 5 gal. buckets of grain from the truck while it was being unloading into the dump pit.
2. Record filter cartridge, filter number, truck and sample number on data sheet.
3. Load filter cartridge in transition using clips.
4. Weigh 3 lbs. of grain in the bucket.
5. Turn sampler on and dump grain in stack.

6. Maintain volumetric flow rate at 75 cfm throughout sampling period.
7. Sample for 3 minutes.
8. Remove and cover filter cartridge.
9. Clean the transition with a brush.
10. Repeat the test four times for grain samples from each truck.

Protocol (G): "Over the Truck" Sampling

The following steps were taken to prepare for sampling:

1. Set up background samplers (one TSP and one PM-10) just outside and upwind of the feed loading shed.
2. Measure and record dimensions of the feed loading shed, clam shell, etc.
3. Enclose the clam shell with plastic so that the feed truck can be driven under forming a dust enclosure between the top of the feed truck and the bottom of the clam shell.
4. Install filter cassettes and zip lock bags on each of the four samplers. Record filter number and bag number being placed on each sampler.
5. Position the four sampling probes (inlet to the pre-separators) to allow for access inside the enclosure described in 3 above.
6. Make sure the samplers are turned off and start generators.
7. Reset timer to zero.

The following steps were taken just prior to, during and upon completion of the sampling period:

1. The safety coordinator obtained the truck driver's and the clam shell operator's cooperation. All instructions and communication with the truck driver clam shell operator were the responsibility of the safety coordinator.
2. Switch the samplers on just as the feed truck approached the shed and set the flow rate at 52 cfm.
3. Allow the feed truck to be driven under the clam shell and the plastic enclosure.
4. Introduce the four sampling probes just inside the plastic enclosure. Check the plastic enclosure to insure that it was draped around all sides of the truck.
5. Indicate to the clam shell operator to dump the feed into the truck.
6. Maintain 52 cfm through each sampler.
7. Switch the samplers off one minute after the truck was loaded and pull the sampling probes away from the truck. Let the truck be driven from underneath the clam shell and leave the shed. If there was an empty feed truck waiting to be filled, leave the samplers on.
8. Record sampling times on data sheet. Record the weights of feed loaded in each truck during the sampling period.
9. Change filter cassettes and zip lock bags after every 3 to 4 trucks in preparation for the next set of trucks.
10. Change background filter cassettes every three hours.

Protocol (H): Grid Sampling

The following steps were taken to prepare for sampling:

1. The background samplers (one TSP and one PM-10) were located approximately 20 meters away from the feed loading shed and another pair just inside the feed loading shed, on the upwind end.
2. Measure and record dimensions of the feed loading shed, dump pit, etc.
3. Position right and left grid stands at their respective side of the downwind opening of the feed loading shed and anchor them with sand bags.
4. Install filter cassettes with filter protection covers and record filter numbers corresponding to each sampling probe.
5. Reset timers to zero on each portable fan unit.

The following steps were taken just prior to, during and upon completion of the sampling period:

1. Remove filter protection covers.
2. Switch the samplers on just as the feed truck approaches the shed and set the flowrate at 40 cfm.
3. Let the feed truck be driven underneath the clam shell and the feed drop inside the truck.
4. Maintain each sampler at a volumetric flow rate of 40 cfm throughout the sampling period.
5. Measure and record air velocity measurements on each side of the feed truck using a hot wire anemometer. Check for variations in wind speed versus vertical height and record results.
6. Let the truck leave the shed following the feed loading operation and get ready for the next truck.
7. Turn the samplers off after every 3 to 4 trucks.
8. Record the weights of feed loaded on each truck.
9. Record sampler times on data sheet.
10. Replace filter protection covers and change cassettes to get ready for the next set of trucks.
11. Change filter cassettes on the background samplers placed inside the shed at the same time that the grid samplers filters are changed.
12. Change the filters on the background samplers located 20 meters away from the feed loading shed, every three hours.

Protocol (I): Grid Sampling

This protocol is exactly the same as Protocol (I) except that instead of using both grid stands at the downwind exit of the feed loading shed, one grid stand was placed just outside the upwind entrance and the other grid stand was placed diagonally opposite just inside the downwind exit of the feed loading shed. The grid stand with three sampling probes (3, 6, and 9 ft high) at the downwind exit of the shed captured the dust emissions due to loading of feed. At the upwind entrance of the shed, the other grid stand with three sampling probes (3, 6, and 9 ft high) sampled the background concentrations. In addition, a pair of background samplers (one HiVol and one PM-10) were placed approximately 20 meters away from the feed loading shed on the upwind side.

Protocol (J): Drop Test

This protocol was exactly the same as Protocol (F) except that instead of dropping one 3 pound sample of grain, two 5 pound samples of feed were dropped for each exposed filter. Air inside the drop test chamber was sampled for 3 minutes for each drop. This modification was made because it was observed that there was a very small amount of dust captured when the drop tests were the high moisture feed.

RESULTS

All of the data sheets associated with the sampling performed in this study are in Appendix B. We organized our data sheets by designating a code for each truck (i.e. B-02 was the second truck sampled at mill B). The emission factor calculations for each protocol are included in Appendix A. Appendix C includes the particle size analyses results including a description of the Coulter Counter Multisizer procedures. A description of the design of the equipment for the grid sampling protocol is included in Appendix D. The design and laboratory testing results of the pre-separator cyclone used in the "under/over the truck" sampling protocols are in Appendix E. Appendix F includes the results of the drop tests performed and the design and laboratory test results used to evaluate this concept. The weather station data are presented in Appendix G. Appendix H is a compilation of the background sampling of ambient concentrations. Appendix I contains the description of the hot wire anemometer data. The average air velocities obtained from this data is compared with the velocity components of the weather station data.

The process used to calculate emission factors from the "under/over the truck" sampling protocols were modified to account for potential sampling losses as follows:

(1) Tests were conducted in the laboratory (Appendix E) to simulate "under the truck" sampling. The results indicated that a maximum of 3% of the dust captured could have been deposited inside the pre-separator cyclone and associated duct prior to the filter. These tests were conducted at loading rates comparable to the rates encountered during grain receiving operations. To be conservative, the total dust captured underneath the truck was increased by 5% before calculating the emission factors for the grain receiving operation.

(2) For sampling above the truck in the feed loading operation, a 10 foot probe was added to the inlet of the pre-separator. The laboratory test results (Appendix E) suggested that no more than 3% of the mass of dust captured was deposited in the extension and pre-separator cyclone. Because of the addition of the 10 foot extension to the probe and to be conservative, the total dust captured above the truck was increased by 10% before calculating the emission factors.

(3) Sampling at the grain receiving shed for Trucks B-03 and B-04 utilized two sampling protocols: "under the truck" and grid. The analyses of this data indicated that the downwind grid samplers were capturing dust that had escaped from the plastic enclosure. When comparing the mass of dust captured by the grid samples to the mass of dust captured simultaneously

by the "under the truck" sampling protocol, the results suggested that approximately 30% of the mass of dust captured by the "under the truck" sampling protocol had escaped (Appendix A). This was attributed to the truck driver opening the hopper bottoms too quickly allowing the grain to flow into the pits at rates faster that 167 bushels per minute which is equivalent to 208 cubic feet per minute (cfm). This did not occur at mills C and D. We modified our "under the truck" protocol to include coordination by our safety director with the truck drivers to slowly open the hopper bottoms. We realize that by slowly opening the hopper bottoms, the time period from the initiation of unloading to choke flow was lengthened resulting in more dust entrained in air but our goal was an increase in accuracy. Although, very little dust escaped the plastic enclosure in mills C and D with this protocol change, the total dust mass captured utilizing the "under the truck" sampling protocol was increased by 30% to account for the possible loss of particulate escaping the plastic enclosure.

With this modification to the procedure for calculating emission factors using the "under the truck" protocol, all of the emission factors using this protocol were increased by 35% (5% to account for dust deposition inside the preseparator plus 30% to account for dust escaping the plastic enclosure). The emission factors using the "over the truck" protocol were increased by 40% (10% to account for dust deposition inside the preseparator plus 30% to account for dust escaping the plastic enclosure).

The volumetric flow rate of air through the shed was an important component in calculating the emission factors for grain unloading and feed loading operations with the grid sampling protocol. It was observed that the wind direction and velocity constantly fluctuated during the sampling periods associated with grain unloading and feed loading. We realized that errors in calculating the volumetric flow rate of air through the shed would result in errors in calculating emission factors. The following general equation was used to calculate emission factors with the grid sampling protocol:

$$EF = (C \cdot Q \cdot t)/(W \cdot 16{,}031) \qquad \text{(Eq. 1)}$$

where, EF = emission factor (pounds of dust entrained in air per ton of grain unloaded),
C = concentration of TSP measured by the grid samplers (grams per cubic meter),
t = sampling time (minutes),
Q = volume rate of flow through the shed (cubic feet per minute), and
W = total mass of grain unloaded (tons).
16,031 = conversion factor

The Q in Equation 1 was determined by multiplying the open area by the average velocity. The open area did not vary. We attempted to use the hot wire anemometer velocity measurements taken during the sampling period (Appendix I) to calculate the average velocity. There were large variations in this data. We chose to use the velocity vector component from the weather station data as our average velocity during the sampling period. The procedure we used to estimate the average velocity during the sampling period is illustrated in Appendix A. It is believed that this decision resulted in a higher velocity and likely resulted in a higher estimated emission factor using the grid sampling protocol. The procedures and calculations used to determine emission factors for the grid sampling protocol are illustrated in Appendix A.

Emission factors calculated using the under and "over the truck" sampling protocols did not require measurements of the volumetric flow rate of air through the shed. Hence, it is likely that the results utilizing these two protocols provided more accurate determinations of grain receiving and feed loading emission factors.

Feed Mill A

The purpose of sampling at Mill A was to test our equipment, procedures and protocols. The data collected at this mill were not used in the calculations of the average emission factors. Although none of the sampling data was used from this trip, it was very beneficial. A number of changes were made to equipment, procedures and protocols including the following:

(1) The plastic enclosure for "under the truck" sampling was modified.

(2) The barrel cyclones used in the "under the truck" sampling were modified.

(3) The grid samplers were fitted with screens to minimize the capture of "bee's wings".

(4) Safety was addressed with a written safety plan and a designation of a safety director.

Feed Mill B

The emission factor results for grain receiving and feed loading for Mill B are given in **Tables 6 & 7**. The average grain unloading emission factor for mill B was 0.0112 lbs/ton with a range of 0.0027 to 0.0235 lbs/ton. The average feed loading emission factor for mill B was 0.0033 lbs/ton with a range of 0.0024 to 0.0042 lbs/ton.

Table 6: Emission Factors (lbs/ton) for Grain Receiving[†]

Truck #	Sampling Technique	Sampling Protocol	Emission Factor lbs/ton
B-01	Grid	C	0.0027
B-03	Under	E	0.0163
B-04	Under	E	0.0060
B-05	Under	A	0.0120
B-06	Under	A	0.0049
B-07	Under	A	0.0129
B-30	Grid	C	0.0235
Average			0.0112
Standard Deviation			0.0073

Ave. 0.0104

† The wind started blowing away from the grid while sampling Truck # B-02. Hence, the data collected for Truck # B-02 were not used in calculating the average emission factor for grain receiving.

Table 7: Emission Factors (lbs/ton) for Feed Loading

Truck #	Sampling Technique	Sampling Protocol	Emission Factor lbs/ton
B-08 to 11	Over	G	0.0042
B-12 to 14	Over	G	0.0036
B-15 to 17	Over	G	0.0035
B-18 to 21	Over	G	0.0028
B-22 to 25	Over	G	0.0031
B-26 to 29	Over	G	0.0024
Average			0.0033
Standard Deviation			0.0006

Feed Mill C

The emission factors for Mill C are given in Tables 8 & 9. The average emission factor for grain unloading (excluding the wheat mids truck was 0.0198 lbs/ton with a range of 0.0033 to 0.071 lbs/ton. The 0.071 lbs/ton was the largest grain unloading emission factor measured in this study. It should be noted that if the average velocity had been 100 fpm instead of the 478 fpm that was derived from the weather station data, this emission factor would have been 0.0149 lbs/ton. This illustrates the importance of the average velocity determination using the grid sampling protocol.

The average feed loading emission factor for mill C was 0.0028 lbs/ton with a range of 0.0003 to 0.0043 lbs/ton. These data are very similar to the data from mill B. Mill C was the largest mill sampled.

Table 8: Emission Factors (lbs/ton) for Grain Receiving

Truck #	Sampling Technique	Sampling Protocol	Emission Factor lbs/ton
C-01	Under	B	0.0054
C-02*	Under	B	0.0018
C-03	Under	B	0.0149
C-04	Under	B	0.0053
C-05	Under	B	0.0033
C-06	Grid	D	0.0711
C-07	Grid	D	0.0144
C-08	Grid	D	0.0081
C-09	Grid	D	0.0104
C-10	Grid	D	0.0590
C-11	Under	B	0.0058
Average			0.0198
Standard Deviation			0.0243

* The emission factor for grain receiving for truck # C-02 was not used in calculating the final average emission factor. The truck was unloading wheat mids.

Table 9: Emission Factors (lbs/ton) for Feed Loading

Truck #	Sampling Technique	Sampling Protocol	Emission Factor lbs/ton
C-12 to 15	Grid	I	0.0003
C-16 to 20	Grid	I	0.0015
C-21 to 24	Grid	I	0.0043
C-25 to 27	Grid	I	0.0040
C-28 to 30	Grid	I	0.0038
Average			0.0028
Standard Deviation			0.0018

Feed Mill D

The emission factors for Mill C are given in Tables 10 & 11. The average milo unloading emission factor was 0.0088 lbs/ton with a range of 0.0038 to 0.0156 lbs/ton. This was the only mill using milo in their feed ration that we encountered in this study. The average corn unloading emission factor was 0.0189 lbs/ton with

0.0185 0.0196
a range of ~~0.185~~ to ~~0.196~~ lbs/ton. The average feed loading emission factor was 0.0043 with a range of 0.0020 to 0.0075 lbs/ton.

X

Table 10: Emission Factors (lbs/ton) for Grain Receiving

Truck #	Sampling Technique	Sampling Protocol	Emission Factor lbs/ton
milo			
D-01*	Under	A	0.0156
D-04*	Under	A	0.0038
D-05*	Under	A	0.0071
Average			0.0088
Standard Deviation			0.0061
corn			
D-03	Under	A	0.0196
D-06	Under	A	0.0186
D-07	Under	A	0.0185
Average			0.0189
Standard Deviation			0.0006

* The emission factors for truck #'s D-01, D-04 and D-05 were for unloading milo and were not used in calculating the final average emission factor since only three data points for milo were collected.

Table 11: Emission Factors (lbs/ton) for Feed Loading

Truck #	Sampling Technique	Sampling Protocol	Emission Factor lbs/ton
D-08 to 11	Grid	H	0.0020
D-12 to 16	Grid	H	0.0035
D-17 to 19	Grid	H	0.0075
D-20 to 24*	Grid	H	0.0381
Average			0.0043
Standard Deviation			0.0028

* While sampling trucks D-20 to 24, there were some external uncontrolled emissions due to the movement of cotton burrs using a front end loader and a feed spill inside the loading shed which contaminated the filters. These results were not used in calculating the final average emission factor.

0.011
The average grain unloading emission factors for mills B, C, and D were 0.012, 0.0198 and 0.0189 lbs/ton, respectively. The average feed loading emission factors for mills B, C, and D were 0.0033, 0.0028, and 0.0043 lbs/ton,
0.020 0.019

respectively. These results suggest that the grain received at mill B contained less free fine dust (FFD) per ton of grain than did the grain at mills C and D. It should be pointed out that the prevailing wind conditions at mill B during the time we were sampling was such that grid sampling was not an option. Hence, the predominant sampling protocol used to measure dust emission rates which were subsequently used to calculate emission factors was the "under the truck" sampling. The emission factor results using this sampling protocol were typically lower than the results using the grid sampling protocol. The feed loading emission factors were very similar for the "over the truck" and grid sampling protocols.

Drop Test

Our goal in performing the drop tests during the sampling trip was to obtain accurate measurements of the free fine dust (FFD) content associated with the different grains and feeds unloaded and loaded, respectively. Ideally, our goal was to use the drop test data to help explain small differences in calculated emission factors. We conducted a number of tests to evaluate the drop test system prior to the sampling trip. It was observed during sampling at mill A that the drop test was not sensitive to fluctuations in grain dust contents and that a higher sampling rate seemed to yield better data. Prior to sampling mills B, C and D, additional tests were conducted. The results of the design and evaluations of our drop test system are included in Appendix F.

The drop test results from the grain and feed samples at mills B, C, and D were not sensitive to small variations in dust content. The dust captured per pound of grain/feed dropped had no relation to the calculated emission factors for grain receiving/feed loading operations. Appendix F contains the results of all of the drop tests conducted. **Table 12** contains a summary of our drop test results.

The average drop test measurement of FFD for the corn samples was 0.381 lbs/ton with a low of 0.14 and a high of 1.29 lbs/ton. The average drop test measurement of FFD for the feed samples was 0.033 lbs/ton with a low of 0.009 and a high of 0.0817 lbs/ton. It appears that on average, the FFD of feed is approximately 10% of the FFD of grain.

Table 12: Summary of Drop Test Results*

Truck #	Grain/Feed Type	Dustiness Ratio TSP (lbs/ton)	Dustiness Ratio Standard Deviation
B-02	Corn	0.4448	0.1603
B-03	Corn	0.4430	0.0314
B-04	Corn	0.3398	0.0846
B-05	Corn	0.2550	0.0203
B-06	Corn	0.3449	0.0399
B-07	Corn	0.3373	0.0358
B-30	Corn	0.1635	0.0172
C-01	Corn	0.3298	0.0146
C-03	Corn	1.2921	0.1398
C-04	Corn	0.2739	0.0227
C-05	Corn	0.2972	0.0255
C-06	Corn	0.2364	0.0298
C-07	Corn	0.1982	0.0231
C-08	Corn	0.1725	0.0379
C-09	Corn	0.1400	0.0130
C-10	Corn	0.8772	0.1190
C-11	Corn	0.2565	0.0134
D-07	Corn	0.2642	0.0114
D-03	Corn	0.5743	0.0133
D-06	Corn	0.3743	0.0313
	Average	**0.3807**	**0.0442**
D-01	Milo	0.2932	0.0392
D-04	Milo	0.3313	0.0657
D-05	Milo	0.2496	0.0336
	Average	**0.2914**	**0.0462**
D-16	Ration #4	0.0817	0.0145
C-12	Ration #5	0.0171	0.0117
C-16	Ration #5	0.0090	0.0063
C-21	Ration #6	0.0222	0.0056
C-28	Ration #6	0.0201	0.0058
	Mixed Feed	0.0477	0.0062
	Average	**0.0330**	**0.0084**
C-02	Wheat Mids	0.3006	0.0873
D-02	Corn Pellets	0.3287	0.0621
	Corn Flakes	0.0617	0.0617
	Cotton Gin Trash	1.6348	0.3692

* See Appendix F for complete explanation of results.

Particle Size Distribution
Particle size distributions were performed on the exposed filters and the dust collected in zip lock bags using the Coulter Counter Multisizer. (See Appendix C.). It should be emphasized that the particle size distributions results using the Coulter Counter procedure represent the percent PM-10 of the fraction of particulate less than 100 micrometers. All particulate larger than 100µm are filtered prior to performing a PSD. The results of the particle size distribution (PSD) analyses for dust captured with the different protocols including the fractions of PM-10 are reported in the **Tables C2-C5**. **Table 13** is a summary of the fraction of PM-10 derived from the PSD results of the dust captured during grain and feed sampling.

EPA (1995d) assumed that the PM-10 emission factor would be 25% of the TSP emission factor for all grains. Our results from the "under the truck" sampling suggest that 12.3% of the TSP is PM-10. The PSD results from the grid sampling suggest that 15.6% of the TSP is PM-10.The combined average percentage PM-10 for "under the truck" sampling and grid sampling was calculated to be 13.6 with a standard deviation of 2.79. We calculated PM-10 emission factors for grain unloading by taking 15% of the TSP emission factors. The higher percent PM-10 values from the grid samples is logical. The "under the truck" samples captured more of the particulate in the 10 to 100 µm range. Many of these particles settled out prior to being captured by the grid samplers.

<u>Table 13: Summary of Percent PM-10 from the PSD Results</u>

Operation	Grain Unloading			Feed Loading	
Protocol	"Under the Truck" Sampling	Grid Sampling	Combined	"Over the Truck" Sampling	Grid Sampling
Average % PM-10	12.30 (n=13)	15.61 (n=7)	13.56 (n=20)	6.40 (n=6)	32.20 (n=8)
Standard Deviation	1.94	2.84	2.79	2.74	6.09

The average percentage PM-10 of particulate captured with "over the truck" sampling was calculated to be 6.4 with a standard deviation of 2.74. PM-10 emission factors for feed loading for the "over the truck" sampling protocol at Feed Mill B were calculated by taking 10% of the TSP emission factors. The only mill that the "over the truck" sampling protocol was used was at feed mill B. The grid sampling protocol for feed loading was not used at this mill because of safety limitations.

The average percentage PM-10 from the PSD analyses for feed grid sampling protocol was calculated to be 32.2 with a standard deviation of 6.09. PM-10 emission factors for feed loading at Feed Mill C and D were calculated by taking 35% of the TSP emission factors.

In summary, our PSD results suggest that the PM-10 emission factor for grain unloading should be calculated by using 15% of the TSP emission factor and the PM-10 emission factor for feed loading may be calculated by using 35% of the TSP emission factor. All of the PSDs from the feed grid sampling were performed on lightly loaded filters with the particulate matter traveling some distance prior to being captured on the filter. It is likely that larger particles settled out prior to being sampled. All of the PSDs from the "under the truck" sampling were performed on samples of grain dust from the zip lock bags and relatively heavily loaded filters. It is our opinion that typical corn dust will have a PM-10 fraction less than 15%. To be conservative, we estimated the grain unloading PM-10 emission factors by multiplying the respective TSP emission factors by 15%. The PSD results from the "over the truck" sampling protocol suggested that the PM-10 fraction was 6.4% in contrast to the PSD results for the grid samples indicating that 32% of the TSP captured was PM-10. It was observed that the "over the truck" sampling had a tendency to capture more larger particles. Feed mill B was loading dry ingredients and mixing in the truck. To be conservative, we estimated the PM-10 emission factors for feed loading at mills C and D by taking 35% of the respective TSP emission factors.

Emission Factors

A summary of the average TSP and PM-10 emission factors results for grain unloading and feed loading operations are given in **Table 14**. The grain unloading emission factors ranged from 0.0027 to 0.0711 lbs/ton (TSP). The feed loading emission factors ranged from 0.0003 to .0075 lbs/ton. In effect, the feed loading emission factor was approximately 10% of the grain unloading emission factor. It is our opinion that the variations in emission factors were a consequence of variations in FFD contents of the grain and feed.

Table 14: Summary of Emission Factors

Truck #	Sampling Technique	TSP (lbs/ton)		PM-10 (lbs/ton)	
		Grain	Feed	Grain	Feed
B-01	Grid	0.0027		0.0004	
B-03	Under	0.0163		0.0024	
B-04	Under	0.0060		0.0009	
B-05	Under	0.0120		0.0018	
B-06	Under	0.0049		0.0007	
B-07	Under	0.0129		0.0019	
B-08 to 11	Over		0.0042		0.0004
B-12 to 14	Over		0.0036		0.0004
B-15 to 17	Over		0.0035		0.0004
B-18 to 21	Over		0.0028		0.0003
B-22 to 25	Over		0.0031		0.0003
B-26 to 29	Over		0.0024		0.0002
B-30	Grid	0.0235	0.0033 [illegible]	0.0035	
C-01	Under	0.0054		0.0008	
C-03	Under	0.0149		0.0022	
C-04	Under	0.0053		0.0008	
C-05	Under	0.0033		0.0005	
C-06	Grid	0.0711		0.0107	
~~C-07~~	~~Grid~~	~~0.0144~~		~~0.0022~~	
C-08	Grid	0.0081		0.0012	
C-09	Grid	0.0104		0.0016	
C-10	Grid	0.0590		0.0089	
C-11	Under	0.0058		0.0009	
C-12 to 15	Grid		0.0003		0.0001
C-16 to 20	Grid		0.0015		0.0005
C-21 to 24	Grid		0.0043		0.0015
C-25 to 27	Grid		0.0040		0.0014
C-28 to 30	Grid		0.0038		0.0013
D-03	Under	0.0196	0.0028 [illegible]	0.0029	
D-06	Under	0.0186		0.0028	
D-07	Under	0.0185		0.0028	
D-08 to 11	Grid		0.0020		0.0007
D-12 to 16	Grid		0.0035		0.0012
D-17 to 19	Grid		0.0075		0.0026
			0.0043 [illegible]		
Average		0.0166	0.0033	0.0025	0.0008
Std Dev		0.0177	0.0016	0.0027	0.0007
Avg. + Std. Dev.		0.0344	0.0050	0.0052	0.0015

We used two very different sampling protocols to estimate emission factors from grain unloading and feed loading operations at feed mills associated with cattle feed yards. **Table 15** contains the average and standard deviations of the emission factors using the two different protocols. It is observed that the "under/over the truck" sampling protocols yielded emission factors with smaller standard deviations than the grid sampling protocol. This result suggests that enclosing the space "under/over the truck" preventing the particulate from escaping with the ambient air and capturing particulate entrained in this space yielded more repeatable measurements of emission rates and ultimately emission factors than the grid protocol which included measuring the concentration and estimating the average volume rate of flow through the shed. It is our view that the difficulties in accurately estimating the volume rate of flow through the shed resulted in the larger standard deviations of emission factors using the grid sampling protocol. All of the emission factor calculations for the "under the truck" sampling protocol incorporated an additional 35% mass to account for potential loss of dust from the enclosure and deposition. In spite of this, the estimated average emission factor with the "under the truck" sampling protocol (0.011 lbs/ton) was 2.5 times less than the average emission factor obtained from the grid sampling (0.027 lbs/ton). In addition, the 0.011 lbs/ton average emission factor using the "under the truck" protocol is slightly less than the average emission factor measured by Kenkel & Noyes (1995) of 0.019 lbs/ton for receiving - hopper bottom trucks (see **Table 4**). All of the trucks sampled in this study were hopper bottom trucks.

Table 15: Emission Factors for the Different Sampling Protocols

Emission Factor	Grain Unloading lbs/ton		Feed Loading lbs/ton	
	"Under the Truck" Sampling	Grid Sampling	"Over the Truck" Sampling	Grid Sampling
Average	0.011 (n=13)	0.027 (n=7)	0.0033 (n=6)	0.0034 (n=8)
Standard Deviation	0.006	0.027	0.0006	0.0022

SUMMARY AND CONCLUSIONS

- **Table 16** contains the average TSP and PM-10 emission factors and associated standard deviations for the grain unloading and feed loading operations at feed mills associated with cattle feed yards. It should be noted that the average grain unloading emission factor for animal feed mills was 0.017 lbs/ton which compares favorably with the 0.019 lbs/ton from receiving hopper bottom reported by Kenkel and Noyes (1995). All of the grain unloaded at the feed mills was unloaded from hopper bottom trucks. The average feed loading emission factor for animal feed mills was 0.003 lbs/to compared to 0.008 lbs/ton for grain shipping (Table 4). The results of the particle size analyses (Tables 9-12) were used to estimate the PM-10 emission factors included in this table. The results associated with all sampling protocols were included in the TSP averages and standard deviations.

Table 16: Averages and Standard Deviations of TSP and PM-10 Measured Emission Factors for Feed Mills

Emission Factor	TSP lbs/ton		PM-10 lbs/ton	
	Grain Unloading	Feed Loading	Grain Unloading	Feed Loading
Average	0.0166	0.0033	0.0025	0.0008
Std. Dev.	0.0177	0.0016	0.0027	0.0007

- It is a conclusion of this study that the "under the truck" sampling protocol for grain receiving operations using the plastic enclosure is a more direct and more accurate procedure for measuring emission factors. This conclusion is not as clear for the "over the truck" sampling protocol. It was difficult to enclose the clam shell with plastic and the feed loading times were short compared to the grain unloading operation. In addition, the batch feed loading rates resulted in intervals of positive pressure within the enclosure i.e., the volume of feed entering the truck was greater than the volume of air being sampled. Sampling at a constant rate of 208 cfm corresponded to a constant feed loading rate of 5,000 pounds of feed (at 25 lbs/ft^3) per minute. The batch feed loading system transferred feed to the truck at rates of 4,000 to over 20,000 pounds per minute. In contrast the grain unloading operation was a semi-continuous process. The only time that the grain unloading rate volume exceeded the sampling volume was during the initial opening of the hopper bottom trucks. The protocol of the "under the truck" sampling addressed this problem by requesting the truck drivers to slowly open their unloading gates. As long as the unloading rate was less than 167 bushels per minute (10,000 bushels per hour), a slight vacuum existed within the plastic enclosure minimizing the escape of dust entrained in the enclosed volume ensuring that our sampling procedures captured all of the dust. This change in the "under the truck" protocol was made when it was observed at feed mill B that the grid sampling simultaneous to the "under the truck" sampling resulted in significant grid filter loadings. It was observed that this change in protocol resulted in very little dust escaping the plastic enclosure at feed mills C and D. However, to be conservative, the total mass of dust captured from each truck using the "under the truck" sampling protocol was increased by 30% to compensate for the potential escape of dust from the plastic enclosure. In spite of the difficulties, the emission factor results using the "over the truck" sampling protocol associated with feed loading was considered to be as accurate or more accurate than the results using the grid sampling protocol. The difficulty in measuring or estimating an accurate volume rate of flow through the shed during the loading or unloading processes in order to calculate accurate emission factors was a problem. Variations in velocity can result in relatively large variations in calculated emission factors. The "under/over the truck" sampling protocols resulted in emission factors that had smaller standard deviations than those associated with the grid sampling protocol (See Table 16).

- There are two reasons for the low emission factor (Table 16) associated with feed loading compared to grain loading at an elevator:
  - (1) Processed feed at feed mills associated with cattle feed yards is typically loaded into trucks at a moisture contents of 20%(wet basis) or higher. The addition of water and steam during the processing of the grain to feed binds the fine dust so that it is not free to become entrained in air. The amount of free dust in the feed that can be entrained in air during the loading process is very small.
  - (2) The use of clam shells to load 4 to 15 tons of feed into a truck in a period of 30 seconds to 3 minutes is not conducive to dust entrainment in air.

- The average emission factor for corn receiving (0.017 lbs/ton) is more than eight times lower than the interim emission factors published by EPA for country grain elevators (0.15 lbs/ton) but is very close to the average emission factor reported by Kenkel & Noyes (1995) of 0.019 lbs/ton. It is likely that the slower rate of unloading grain at a feed mill as a consequence of smaller pits and slower legs compared to elevators would result in lower emission factors. A typical feed mill pit will hold 400 bushels. A typical grain truck will contain 1,000 bushels. Approximately 3 minutes after initiating the truck unloading operation, choke flow exists. This condition can be described as grain backing up to the hopper bottom from the pit. During choke flow, very little dust is entrained in the air. Choke flow seldom occurs at grain elevators during the

for wheat not corn

unloading operation. The pit capacities of grain elevators are larger and the rate of removal of grain from the pit is faster.

- The average emission factor for the feed loading operation (.003 lbs/ton) is more than ten times lower than the Interim Emission Factor published by EPA (1995) for corn shipping (0.04 lbs/ton). This result is not surprising. Grain shipping at an elevator involves the continuous transfer of grain through a spout with a FFD equal to or greater than 1. The loading of high moisture feed at feed mills is a batch process and the feed has an estimated FFD of less than 0.2 lbs/ton. The loading process at feed mills is significantly different than the continuous grain shipping process at grain elevators.

- The concept proposed in this report of using an average emission factor plus one standard deviation based upon actual measurements in the field has merit. It would not be prudent to establish an emission factor that would result in an allowable emission rate (AER) established by a SAPRA that was too low. SAPRAs use EPA emission factors in calculating the facility's maximum allowable emission rate. If EPA were to establish an emission factor lower than the average, many facilities would be emitting particulate matter at rates that would be in violation of their permit and be subject to monetary penalties.

- EPA (1995d) proposed the following model for interim emission factors for grain elevators:

$$EF = A * DR \qquad \text{(Eq. 2)}$$

where, EF = emission factor (pounds of dust entrained in air per ton of grain or feed transferred),
A = emission factor normalized to wheat (pounds of dust entrained in air per ton if wheat were the grain handled; calculated by dividing the emission factor for any given grain by its DR), and
DR = dustiness ratio (relative dustiness of grain handled compared to wheat).

The "A" value in this equation was the average emission factor reported by Kenkel & Noyes (1995). This average incorporated data from hopper bottom, receiving end dumps, and floor sweepings. Equation 2 can be interpreted as follows: If the DR represented the FFD present in the grain in lbs/ton, "A" would be the fraction of the FFD entrained in air by the grain or feed transfer process. It is logical that only a fraction of the FFD content of grain will be entraining during a transfer.

- We are proposing to modify this model to facilitate broader applicability to various grain handling processes. The dustiness ratio for corn reported in the interim AP-42 document (EPA 1995d), corresponds closely to free fine dust content (FFD) values reported by Parnell et al (1986). These FFD values represent the pounds of free dust less than 100μm per ton of grain as determined by the "air wash" procedure (Parnell, 1986). Using the dust content rather than the dustiness ratio gives the following model:

$$EF = F * FFD \qquad \text{(Eq. 3)}$$

where, EF = emission factor (pounds of dust entrained in air per ton of grain or feed transferred),
F = fraction of the free dust in the grain entrained in air at a transfer point, and
FFD = free fine dust content (pounds of free dust less than 100μm per ton of grain or feed).

Note: The term "free" dust has been used in this report to more accurately reflect the fine (less than 100μm) dust content of grain and feed that is available to be entrained in air which can subsequently result in impacting the public downwind. High moisture feed will contain more free fine dust than dry grain if it were dried and subjected to an air wash test (see Appendix D) but in the high moisture feed this fine dust is not free to be entrained in the air during a feed transfer. Similarly, grain treated with mineral oil will have less free fine dust per ton than untreated grain.

The "F" in equation 3 refers to the fraction of the free fine dust in the grain entrained in air at the transfer point. If the fraction of dust entrained in air in a grain unloading operation were constant, the "F" could be calculated by dividing the emission factor by the FFD. For an emission factor of 0.04 lbs/ton and an FFD of 2.5 lbs/ton (corn), the fraction of the FFD entrained in air would be 0.016. Therefore, 1.6% of the free fine dust in the corn is entrained during the unloading process at a feed mill. This model facilitates the calculation of emission factors based on the free fine dust content of the material being handled and the "F" value of the handling operation. This model has an added advantage that the terms are measurable physical characteristics of the grain and the grain handling process. It is likely that the fraction of FFD entrained in air is constant when unloading grain from a hopper bottom truck into a pit.

- If the model described by equation 3 were to be utilized by EPA to determine emission factors for feed mills and the EPA (1995d) DR values were used as FFD values, the equations for calculating the feed mill emission factors for different grains are listed in Table 17. For example, the emission factor for unloading wheat at a feed mill would be calculated with the following equation:

$$EF = 0.016 \bullet (1 \text{ lbs/ton}) = 0.016 \text{ lbs/ton} \qquad \text{(Eq. 4)}$$

Table 17: Proposed Emission Factors for Feed Mills

Emission Factor	TSP (lbs/ton)		PM-10 (lbs/ton)	
	General	For Corn	General	For Corn
Grain Unloading	0.016FFD	0.04	0.0024FFD	0.006
Feed Loading	0.002FFD	0.005	0.0006FFD	0.002

- Expanding this concept to other grains, the expected emission factors for different grains using the EPA DR values as FFD values are presented in **Table 18**. This concept of calculating emission factors for grain unloading and feed loading at feed mills using different grains incorporated the following assumptions:
  (1) The free fine dust (FFD) content is accurately depicted by the EPA (1995d) DR values.
  (2) The fraction of dust entrained in air for grain unloading is 0.016 (1.6%) of the fine dust content of grain.
  (3) We propose that the emission factor for feed be estimated using the FFD value of the parent grain. We know that this is inaccurate because the FFD values of high moisture feed are relatively small compared to grain. However, it is difficult to accurately measure the FFD of high moisture feed with an air wash test because of the requirement that the moisture content of the feed sample would have to be maintained constant during the test. Our recommendation is to use a smaller fraction of dust entrainment ("F" value) with the parent grain FFD value. In this case, the fraction of TSP that would be entrained in air while loading feed would be 0.002 (0.2%). (See Table 15.) In reality, the FFD for high moisture feed is approximately 10% of the parent grain FFD which suggests that approximately 2% of the free dust in the feed is entrained in air during the feed loading operation.

- The primary grain of choice at feed mills associated with cattle feed yards is corn. Using the concept of the average emission factor plus one standard deviation, our study suggests that the emission factors associated with corn unloading and feed loading should be 0.04 and 0.005 lbs/ton, respectively. (See Table 17.)
  0.006

Table 18 illustrates the particulate emission rates for various grains during the unloading of grain and the loading of feed at an animal feed mill using our proposed emission factors. These data are based on measured emission factors for corn and FFD contents equal to the dustiness ratio data reported in the AP-42 Interim report.

Table 18: Emission Factors for Different Grains

Grain Type	Free Fine Dust (FFD) lbs/ton	TSP (lbs/ton)		PM-10 (lbs/ton)	
		Grain Unloading	Feed Loading	Grain Unloading	Feed Loading
Corn	2.50	0.040	0.005	0.006	0.002
Wheat	1.00	0.016	0.002	0.002	0.001
Milo	1.75	0.028	0.004	0.004	0.001
Soybean	2.50	0.040	0.005	0.006	0.002
Mixed	1.95	0.031	0.004	0.005	0.001

- It is a conclusion of this study that the Drop Test system of measuring FFD contents of grain or feed is not recommended as a replacement for the DR values listed in the EPA interim AP-42 factors (1995d). The "under the truck" and grid sampling results were significantly more sensitive to variations in grain dust content than were the drop test results. Justifications for this conclusion are as follows:
  (1) The drop tests were performed on a small fraction of the grain and feed loads. To obtain representative samples of the grain from a truck when the fine dust may not be uniformly distributed is difficult. Obtaining representative samples of feed is not as difficult since the mill is mixing the feed just prior to delivery to the bunks.
  (2) The capture velocity of the sampling system associated with the drop test was in excess of 6,000 fpm. It is likely that the high capture velocities resulted in large particles being sampled. A few large particles can skew the measurement of fine dust content of grain. This can be altered with some minor engineering design changes. However, this method of measuring FFD will never be as aggressive as the air wash test and will not yield accurate FFD data.
  (3) The FFD values measured with our drop test system were in the range of 0.35 lbs/ton for corn (see Table 12) which is significantly less than 2.5 lbs/ton. It is our opinion that the 2.5 lbs/ton is a more accurate representation of the free fine dust content of corn than 0.35 lbs/ton measured by our drop tests. If a more aggressive free dust content measurement were to be used such as the air wash test (Parnell et al, 1994), 2.5 lbs per ton would be typical of the fine dust content of corn.

The results of the particle size analyses suggest that 15% of the particulate emitted during the grain unloading operation was PM-10 (see Tables **C-2, C-3 &**

C6). It is a conclusion of this study that 15% of the particulate entrained in air during the grain unloading operation is PM-10. The average of all PM-10 measurements for corn and milo was 14%. The particle size analyses of the dust emitted during the feed loading operation suggest that 35% of the particulate entrained in air was PM-10 (see Tables C-4 & C-5). Data for the percent PM-10 for feed loading operation was more variable than for grain unloading. The samples of dust captured during feed unloading with the grid sampling protocol were relatively small. The PSDs performed using the "over the truck" protocol suggest that the percent PM-10 was 6.4 versus 32.2 from the grid samples. The emission factors of the feed loading operation was very small compared to grain unloading. Feed is the result of a size reduction process and could have a higher percentage PM-10. We used 35% PM-10 in this study to be conservative. It is possible that the average PM-10 for feed unloading could be 25%.

NOMENCLATURE

AER	- Allowable Emission Rate
DEQ	- Department of Environmental Quality
DR	- Dustiness Ratio
EPA	- Environmental Protection Agency
FCAA	- Federal Clean Air Act
FFD	- Free Fine Dust
FOP	- Federal Operating Permit
PM-10	- Particulate Matter less than 10 microns
PSD	- Particle Size Distribution
SAPRA	- State Air Pollution Regulatory Agency
TSP	- Total Suspended Particulate

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APPENDIX A

SAMPLE CALCULATIONS

Protocols (A) & (B): "Under the Truck" Sampling for Grain Unloading

<u>Truck # C-03</u>: (see Table A-1 on page A-4)

Exposed filters and zip lock bags were weighed and their pre-weights deducted to calculate the total mass of dust captured on the filters and in the bags.

Total mass of dust on filters ($f_7+f_8+f_9+f_{10}$), gm
$= 0.10+0.23+0.15+0.40$
$= 0.89$

Total mass of dust in bags ($z_7+z_8+z_9+z_{10}$), gm
$= 38.65+42.65+45.89+15.04$
$= 142.22$

Tests conducted in the laboratory indicated that 3% of the dust loaded at the rates encountered during the grain receiving operation was deposited inside the pre-separator. To be conservative, 5% of the total dust captured underneath the truck was added before calculating the emission factors for the grain receiving operation.

Estimated mass of dust deposited in pre-separator (d), gm
= 5% of dust captured on filters and in bags
$= 0.05 \times [\Sigma f_i + \Sigma z_i]$; $i = 7$ to 10
$= 0.05 \times [0.89 + 142.22]$
$= 7.16$

Sampling at the grain receiving shed for Truck #'s B-03 and B-04 was done using the plastic enclosure underneath the truck and the grid at the downwind opening of the shed. The analysis of this data indicated that the grid samplers were capturing dust that escaped from the plastic enclosure. This analysis indicated that the mass of dust escaping was 30% of that captured inside the plastic enclosure underneath the truck. Hence, before calculating emission factors for trucks sampled only with the plastic enclosure underneath the truck, an additional 30% of the dust captured was added to account for the dust lost from the plastic enclosure.

Estimated mass of dust that escaped from the enclosure (e), gm
= 30% of total dust captured
$= 0.3 \times [\Sigma f_i + \Sigma z_i + d]$
$= 0.3 \times [0.89 + 142.22 + 7.16]$

$$= 45.08$$

Mass of grain unloaded from truck (M), lbs = 54460

Total mass of dust emitted (m), gm = mass of dust captured on the filters + mass of dust captured in the bags + mass of dust deposited in the cyclone pre-separator + mass of dust escaped from the plastic enclosure.

$$\text{Total mass of dust emitted (m), gm} = \sum_{i=7}^{10} f_i + \sum_{i=7}^{10} z_i + d + e$$

$$= 0.89 + 142.22 + 7.16 + 45.08$$

$$= 195.34$$

The emission factor was calculated by dividing the pounds of dust emitted by the tons of grain unloaded from the truck.

$$\text{Emission Factor, lbs / ton} = \frac{m \times 2000}{M \times 454}$$

$$= \frac{195.34 \times 2000}{54460 \times 454}$$

$$= 0.0149$$

Table A-1: Data Sheet for Truck# C-03

Data

Date/Time:	6-13-96/8:50
Sampling protocol:	(B) Under the Truck Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	13.53
Mass of grain handled, lb:	57600

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	304	0.09847	71	38.65026
8	305	0.23255	72	42.65232
9	306	0.15485	73	45.88533
10	313	0.39970	74	15.03558

Calculated Values

Total mass of dust on filters, gm	=	0.8856
Total mass of dust in bags, gm	=	142.2235
Efficiency of cyclone pre-separator, %	=	99.3812
Estimated mass of dust deposited in pre-separator, gm	=	7.1555
Estimated mass of dust escaped from enclosure, gm	=	45.0794
Total mass of dust, gm	=	195.3439
Emission Factor, lbs/ton	=	**0.0149**

Protocols (C), (D) & (H): Grid Sampling for Grain Unloading and Feed Loading

Truck # C-07: (see **Table A-2** on page A-8)

Exposed filters were weighed and their pre-weights deducted to calculate the total mass of dust captured on the filters.

Mass of dust captured on each grid filter (f_1, f_2, f_3, f_4, f_5, f_6), gm
= 0.07, 0.05, 0.04, 0.07, 0.24, 0.67

Mass of dust captured on the background filter (f_B), gm
= 0.15

The grid and background samplers were calibrated at standard temperature and pressure to operate at a flowrate of 40 cfm. The actual sampling rates were calculated for actual temperatures and pressures using the formula given below:

$$\text{Sampling rate (q), cfm} = 5.976 \times K \times Do^2 \times \sqrt{\frac{\Delta P}{\rho}}$$

where; K = orifice coefficient
Do = diameter of orifice, inch
ΔP = pressure difference across the orifice, inches H_2O
ρ = density of air, lb/ft^3

Sampling rate for grid samplers (q), cfm = 43

Sampling rate for background sampler (q_b), cfm
= 51

Sampling time for grid samplers (t_1, t_2, t_3, t_4, t_5, t_6), min
= 20.0,20.0,20.0,20.2,20.2,20.2

Sampling time for background samplers (t_B), min
= 200.0

Sampling area associated with each grid sampler (a_1, a_2, a_3, a_4, a_5, a_6), ft^2
(shown in Figure A-1) = 25, 6, 29, 29, 6, 25

Average wind direction during sampling period from weather station data (W), deg
= 133

Grid direction (X), deg = 90

Average wind velocity during sampling period from weather station data (V), fpm = 494

Mass of grain/feed handled (M), lbs = 56220

Background filter loading rate (c_B), gm / m^3 $= \dfrac{f_B \times 35.31}{q_B \times t_B}$

$= \dfrac{0.15 \times 35.31}{51 \times 200}$

$= 0.0005$

Grid filter loading rate (c_i), gm / m^3 $= \dfrac{f_i \times 35.31}{q \times t_i}$; where, i = 1 to 6

c_1, gm / m^3 $= \dfrac{0.07 \times 35.31}{42 \times 20.0}$

$= 0.0027$

similarly, c_2, c_3, c_4, c_5, c_6, gm / m^3 = 0.0021, 0.0017, 0.0029, 0.0098, 0.0272

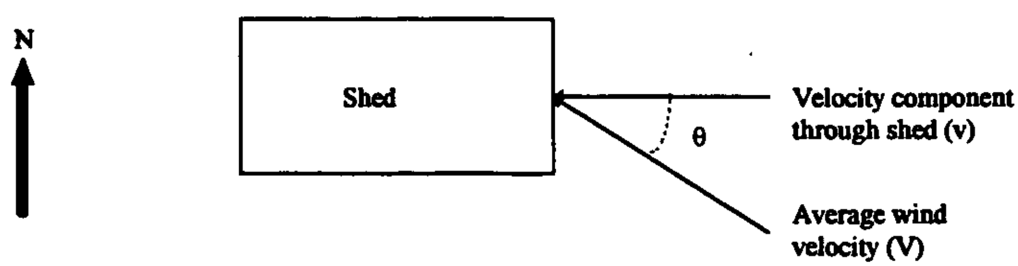
Corrected loading rate (C_i), gm / m^3 $= c_i - c_B$; where, i = 1 to 6

C_1, gm / m^3 $= 0.0027 - 0.0005$

$= 0.0022$

similarly, C_2, C_3, C_4, C_5, C_6, gm / m^3 = 0.0016, 0.0012, 0.0024, 0.0093, 0.0267

The velocity of the wind component through the shed (v) is calculated by multiplying the average wind velocity (V) with the cosine of the angle (θ) between the grid direction (X) and the average wind direction (W) during the sampling period from the weather station data, as shown in the diagram below:



$$\text{Velocity component through shed (v), fpm} = V \cos|\theta| = 494 \cos|133 - 90| = 361$$

$$\text{Total Dust Emitted (m), lbs} = \sum_{i=1}^{6} \frac{(C_i \times v \times a_i \times t_i)}{35.31}$$

$$= \frac{0.0022 \times 361 \times 25 \times 20.0}{35.31} + \ldots$$

$$\ldots + \frac{0.0267 \times 361 \times 25 \times 20.2}{35.31}$$

$$= 11.07 + 2.01 + 7.22 + 14.34 + 11.54 + 138.15$$

$$= 184.34$$

The emission factor was calculated by dividing the pounds of dust emitted by the tons of grain unloaded from the truck.

$$\text{Emission Factor, lbs / ton} = \frac{m \times 2000}{M \times 454} = \frac{184.34 \times 2000}{56220 \times 454} = 0.0144$$

Table A-2: Data Sheet for Truck# C-07

Data

Date/Time: 6-13-96/2:00
Sampling Protocol: (D) Grid Sampling for Grain Unloading
Grain Type: Corn
Moisture content of grain, %: 13.70
Grid Direction, deg: 90
Avg. wind direction, deg: 133
Avg. wind vel. (weather stn.), fpm: 494
Avg. wind vel. (anemometer), fpm: 325
Mass of grain handled, lb: 56220

Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	374	0.0651	43	20.00
2	362	0.0523	43	20.00
3	375	0.0420	43	20.00
4	378	0.0713	43	20.20
5	377	0.2414	43	20.20
6	376	0.6702	43	20.20
background PM10	291	0.0467	43	200.00
background TSP	346	0.1467	51	200.00

Calculated Values

Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust emitted
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0027	0.0022	361	25	11.0707
2	0.0021	0.0016	361	6	2.0149
3	0.0017	0.0012	361	29	7.2240
4	0.0029	0.0024	361	29	14.3387
5	0.0098	0.0093	361	6	11.5414
6	0.0272	0.0267	361	25	138.1532
background PM10	0.0002				
background TSP	0.0005				

Total dust emitted, gm = 184.3429
Emission Factor (lbs/ton) = 0.0144

Protocol (E): "Under the Truck" and Grid Sampling for Grain Unloading

Truck # B-04: (see Table A-3 on page A-12)

Exposed filters and zip lock bags were weighed and their pre-weights deducted to calculate the total mass of dust captured on the filters and in the bags.

Mass of dust captured on each grid filter (f_1, f_2, f_3, f_4, f_5, f_6), gm
= 0.03,0.04,0.03,0.04,0.03,0.04

Mass of dust captured on the background filter (f_B), gm
= 0.09

Total mass of dust on filters from under the truck ($f_7 + f_8 + f_9 + f_{10}$), gm
= 0.04 + 0.05 + 0.04 + 0.05
= 0.18

Total mass of dust in bags from under the truck (z_7, z_8, z_9, z_{10}), gm
= 12.18 + 10.00 + 10.31 + 25.68
= 58.13

Tests conducted in the laboratory indicated that 3% of the dust loaded at the rates encountered during grain receiving operation was deposited inside the pre-separator. To be conservative, 5% of the total dust captured underneath the truck was added before calculating the emission factors for the grain receiving operation.

Estimated mass of dust deposited in pre-separator (d), gm
= $0.05 \times [\,\Sigma f_i + \Sigma z_i\,]$; i = 7 to 10
= 0.05 x [0.18 + 58.13]
= 2.92

The grid and background samplers were calibrated at standard temperature and pressure to operate at a flowrate of 40 cfm. The actual sampling rates were calculated for actual temperatures and pressures using the formula given below:

$$\text{Sampling rate (q), cfm} = 5.976 \times K \times Do^2 \times \sqrt{\frac{\Delta P}{\rho}}$$

where; K = orifice coefficient
Do = diameter of orifice, inch
ΔP = pressure difference across the orifice, inches H_2O
ρ = density of air, lb/ft^3

Sampling rate for grid samplers (q), cfm = 44

Sampling rate for background sampler (q_B), cfm
= 52

Sampling time for grid samplers (t_1, t_2, t_3, t_4, t_5, t_6), min
= 9.4, 9.4, 9.4, 9.35, 9.35, 9.35

Sampling time for background samplers (t_B), min
= 231.0

Sampling area associated with each grid sampler (a_1, a_2, a_3, a_4, a_5, a_6), ft^2
(shown in **Figure A-1**) = 25, 6, 29, 29, 6, 25

Average wind direction during sampling period from weather station data (W), deg
= 35

Grid direction (X), deg = 90

Average wind velocity during sampling period from weather station data (V), fpm
= 343

Mass of grain unloaded from truck (M), lbs = 56980

Background filter loading rate (c_B), gm / m^3 $= \dfrac{f_B \times 35.31}{q_B \times t_B}$

$= \dfrac{0.09 \times 35.31}{52 \times 231}$

$= 0.0003$

Grid filter loading rate (c_i), gm / m^3 $= \dfrac{f_i \times 35.31}{q \times t_i}$; where, i = 1 to 6

c_1, gm / m^3 $= \dfrac{0.03 \times 35.31}{44 \times 9.4}$

$= 0.0027$

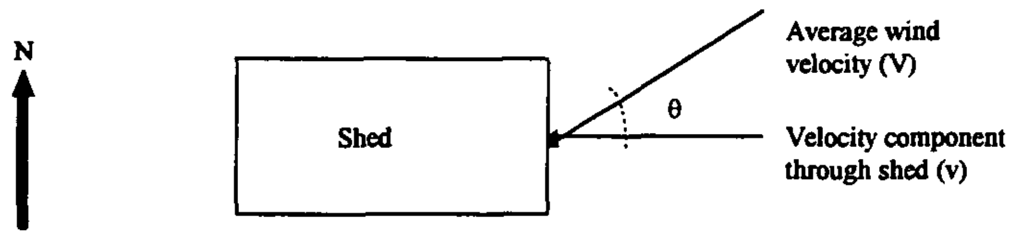
similarly, c_2, c_3, c_4, c_5, c_6, gm / m^3 = 0.0031, 0.0022,
0.0031, 0.0024, 0.0032

Corrected loading rate (C_i), gm / m^3 = $c_i - c_B$; where, i = 1 to 6

C_1, gm / m^3 = 0.0027 - 0.0003
= 0.0024

similarly, C_2, C_3, C_4, C_5, C_6, gm / m^3 = 0.0028, 0.0020,
0.0028, 0.0021, 0.0030

The velocity of the wind component through the shed (v) is calculated by multiplying the average wind velocity (V) with the cosine of the angle (θ) between the grid direction (X) and the average wind direction (W) during the sampling period from the weather station data, as shown in the diagram below:



$$\text{Wind vel. component through shed (v), fpm} = V \cos|\theta| = 343 \cos 55 = 197$$

$$\text{Mass of dust escaped from enclosure } (m_E)\text{, lbs} = \sum_{i=1}^{6} \frac{(C_i \times v \times a_i \times t_i)}{35.31}$$

$$= \frac{0.0024 \times 197 \times 25 \times 9.4}{35.31} + \ldots$$

$$\ldots. + \frac{0.0030 \times 197 \times 25 \times 9.35}{35.31}$$

$$= 3.17 + 0.89 + 2.97 + 4.28 + 0.67 + 3.89$$

$$= 15.86$$

Total mass of dust emitted (m), gm = mass of dust captured on the filters + mass of dust captured in the bags + mass of dust deposited in the cyclone pre-separator + mass of dust escaped from the plastic enclosure.

$$\text{Total mass of dust emitted (m), gm} = \sum_{i=7}^{10} f_i + \sum_{i=7}^{10} z_i + d + m_E$$

$$= 0.18 + 58.13 + 2.92 + 15.86$$

$$= 77.08$$

The emission factor was calculated by dividing the pounds of dust emitted by the tons of grain unloaded from the truck.

$$\text{Emission Factor, lbs / ton} = \frac{m \times 2000}{M \times 454}$$

$$= \frac{77.08 \times 2000}{56980 \times 454}$$

$$= 0.0060$$

Table A-3: Data Sheet for Truck# B-04

Data

Date/Time:	6-10-96/12:25
Sampling Protocol:	(E) Under/Grid Sampling for Grain Unloading
GrainType:	Corn
Moisture content of grain, %:	12.75
Grid direction, deg:	90
Avg. wind direction, deg:	35
Avg. wind vel. (weather stn.), fpm:	343
Avg. wind vel. (anemometer), fpm:	113
Mass of grain handled, lb:	56980

Grid Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	211	0.0314	44	9.40
2	213	0.0361	44	9.40
3	203	0.0260	44	9.40
4	210	0.0361	44	9.35
5	205	0.0280	44	9.35
6	204	0.0378	44	9.35
background PM10	185	0.0560	44	231.00
background TSP	183	0.0891	52	231.00

Under Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	209	0.0433	23	12.1779
8	208	0.0473	24	9.9710
9	207	0.0390	25	10.3079
10	206	0.0468	26	25.6758

Calculations

Grid Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0027	0.0024	197	25.00	3.1699
2	0.0031	0.0028	197	6.00	0.8848
3	0.0022	0.0020	197	29.00	2.9713
4	0.0031	0.0028	197	29.00	4.2787
5	0.0024	0.0021	197	6.00	0.6689
6	0.0032	0.0030	197	25.00	3.8868
background PM10	0.0002				
background TSP	0.0003				

Total mass of dust escaped from enclosure, gm	=	15.8605
Total mass of dust on filters from under the truck, gm	=	0.1764
Total mass of dust in bags from under the truck, gm	=	58.1325
Efficiency of cyclone pre-separator, %	=	99.6975
Estimated mass of dust deposited in pre-separator, gm	=	2.9154
Total mass of dust, gm	=	77.0849
Emission Factor, lbs/ton	=	**0.0060**

Protocol (G): "Over the Truck" Sampling for Feed Loading

<u>Truck # B-15 to B-17</u>: (see Table A-4 on page A-15)

Exposed filters and zip lock bags were weighed and their pre-weights deducted to calculate the total mass of dust captured on the filters and in the bags.

Total mass of dust on filters $(f_7+f_8+f_9+f_{10})$, gm
$$= 0.02 + 0.03 + 0.02 + 0.04$$
$$= 0.11$$
Total mass of dust in bags $(z_7+z_8+z_9+z_{10})$, gm
$$= 2.50 + 3.44 + 3.75 + 4.04$$
$$= 13.73$$

Tests conducted in the laboratory indicated that 3% of the dust loaded at the rates encountered during grain receiving operation was deposited inside the pre-separator. To be conservative, 10% of the total dust captured above the truck was added before calculating the emission factors for the feed loading operation.

Estimated mass of dust deposited in pre-separator (d), gm
= 10% of dust captured on filters and in bags
$$= 0.1 \times [\, \Sigma f_i + \Sigma z_i \,] \; ; \; i = 7 \text{ to } 10$$
$$= 0.1 \times [0.11 + 13.73]$$
$$= 1.38$$

Sampling at the grain receiving shed for Truck #'s B-03 and B-04 was done using the plastic enclosure underneath the truck and the grid at the downwind opening of the shed. The analysis of this data indicated that the grid samplers were capturing dust that escaped from the plastic enclosure. This analysis indicated that the mass of dust escaping was 30% of that captured inside the plastic enclosure. Hence, before calculating emission factors for trucks sampled only with the plastic enclosure above the truck, an additional 30% of the dust captured was added to account for the dust lost from the plastic enclosure.

Estimated mass of dust escaped from enclosure (e), gm
= 30% of total dust captured
$$= 0.3 \times [\, \Sigma f_i + \Sigma z_i + d \,]$$
$$= 0.3 \times [0.11 + 13.73 + 1.38]$$
$$= 4.57$$

Mass of feed loaded on the truck (M), lbs = 24600

Total mass of dust emitted (m), gm = mass of dust captured on the filters + mass of dust captured in the bags + mass of dust deposited in the cyclone pre-separator + mass of dust escaped from the plastic enclosure.

$$\text{Total mass of dust emitted (m), gm} = \sum_{i=7}^{10} f_i + \sum_{i=7}^{10} z_i + d + e$$
$$= 0.11 + 13.73 + 1.38 + 4.57$$
$$= 19.79$$

The emission factor was calculated by dividing the pounds of dust emitted by the tons of feed loaded on the trucks.

$$\text{Emission Factor, lbs / ton} = \frac{m \times 2000}{M \times 454}$$
$$= \frac{19.79 \times 2000}{24600 \times 454}$$
$$= 0.0035$$

Table A-4: Data Sheet for Truck# B-15 to B-17

Data

Date/Time:	6-11-96/7:20 to 7:41
Sampling protocol:	(G) Over the Truck Sampling for Feed Loading
Feed Type:	Ration# 6
Mass of feed handled, lb:	24600

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	281	0.0218	47	2.4965
8	280	0.0308	48	3.4430
9	279	0.0195	49	3.7490
10	278	0.0376	50	4.0404

Calculated Values

Total mass of dust on filters, gm	=	0.1097
Total mass of dust in bags, gm	=	13.7289
Efficiency of cyclone pre-separator, %	=	99.2073
Estimated mass of dust deposited in pre-separator, gm	=	1.3839
Estimated mass of dust escaped from enclosure, gm	=	4.5667
Total mass of dust, gm	=	19.7892
Emission Factor, lbs/ton	=	**0.0035**

Protocol (I): Grid Sampling for Feed Loading

<u>Truck # C-28 to C-30</u>: (see Table A-5 on page A-19)

Exposed filters were weighed and their pre-weights deducted to calculate the total mass of dust captured on the filters.

Mass of dust captured on each downwind grid filter (f_1, f_2, f_3), gm
= 0.11, 0.08, 0.06

Mass of dust captured on each upwind grid filter (f_4, f_5, f_6), gm
= 0.04, 0.04, 0.04

The grid and background samplers were calibrated at standard temperature and pressure to operate at a flowrate of 40 cfm. The actual sampling rates were calculated for actual temperatures and pressures using the formula given below:

$$\text{Sampling rate (q), cfm} = 5.976 \times K \times Do^2 \times \sqrt{\frac{\Delta P}{\rho}}$$

where; K = orifice coefficient
Do = diameter of orifice, inch
ΔP = pressure difference across the orifice, inches H_2O
ρ = density of air, lb/ft^3

Sampling rate (q), cfm = 43

Sampling time for downwind grid samplers (t_1, t_2, t_3), min
= 33.0, 33.0, 33.0

Sampling time for upwind grid samplers (t_4, t_5, t_6), min
= 33.0, 33.0, 33.0

Sampling area associated with downwind grid samplers (a_1, a_2, a_3), ft^2
(shown in Figure A-1) = 54, 36, 66

Average wind direction during sampling period from weather station data (W), deg
= 117

Grid direction (X), deg = 90

Average wind velocity during sampling period from weather station data (V), fpm
= 535

Mass of feed loaded on truck (M), lbs = 90670

Upwind grid filter loading rates (c_{Ui}), gm / m^3 $= \dfrac{f_i \times 35.31}{q \times t_i}$; where i = 4 to 6

c_{U1}, gm / m^3 $= \dfrac{0.04 \times 35.31}{43 \times 33}$

= 0.0009

similarly, c_{U2}, c_{U3} = 0.0009, 0.0011

Average upwind concentration (c_U), gm / m^3 $= \dfrac{c_{U1} + c_{U2} + c_{U3}}{3}$

= 0.0010

Downwind grid filter loading rates (c_{Di}), gm / m^3 $= \dfrac{f_i \times 35.31}{q \times t_i}$; where, i = 1 to 3

c_{D1}, gm / m^3 $= \dfrac{0.11 \times 35.31}{43 \times 33}$

= 0.0029

similarly, c_{D2}, c_{D3}, gm / m^3 = 0.0021, 0.0015

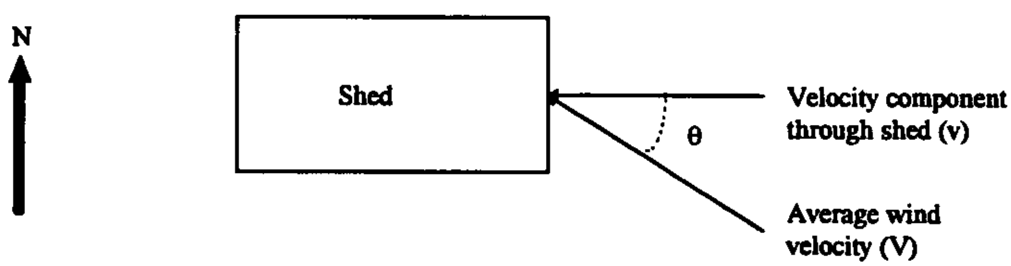
Corrected loading rate (C_i), gm / m^3 = c_{Di} - c_U; where, i = 1 to 3

C_1, gm / m^3 = 0.0029 - 0.0010

= 0.0019

similarly, C_2, C_3, gm / m^3 = 0.0011, 0.0005

The velocity of the wind component through the shed (v) is calculated by multiplying the average wind velocity (V) with the cosine of the angle (θ) between the grid direction (X) and the average wind direction (W) during the sampling period from the weather station data, as shown in the diagram below:



$$\text{Wind velocity component through shed (v), fpm} = V \cos|\theta| = 535 \cos|117 - 90| = 477$$

$$\text{Total Dust Emitted (m), lbs} = \sum_{i=1}^{3} \frac{(C_i \times v \times a_i \times t_i)}{35.31}$$

$$= \frac{0.0019 \times 477 \times 54 \times 33.0}{35.31} + \ldots\ldots\ldots \ldots\ldots + \frac{0.0005 \times 477 \times 66 \times 33.0}{35.31}$$

$$= 45.17 + 17.72 + 15.69$$

$$= 78.57$$

The emission factor was calculated by dividing the pounds of dust emitted by the tons of feed loaded on the trucks.

$$\text{Emission Factor, lbs / ton} = \frac{m \times 2000}{M \times 454} = \frac{78.57 \times 2000}{90670 \times 454} = 0.0038$$

Table A-5: Data Sheet for Truck# C-28 to 30

Data

Date/Time: 6-14-96/13:45 to 14:45
Sampling protocol: (I) Grid Sampling for Feed Loading
Feed Type: Ration# 6
Grid direction, deg: 90
Avg. wind direction, deg: 117
Avg. wind vel. (weather stn.), fpm: 535
Avg. wind vel. (anemometer), fpm: 300
Mass of feed handled, lb: 90670

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
Downwind	454	0.1146	43	33.00
2	407	0.0835	43	33.00
3	453	0.0606	43	33.00
Upwind	451	0.0368	43	33.00
5	450	0.0371	43	33.00
6	452	0.0435	43	33.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
Downwind	0.0029	0.0019	477	54	45.1708
2	0.0021	0.0011	477	36	17.7168
3	0.0015	0.0005	477	66	15.6868
Upwind	0.0009				
5	0.0009				
6	0.0011				

Total dust emitted, gm = 78.5745
Emission Factor (lbs/ton) = **0.0038**

Protocols (F) & (J): Drop Test for Grain and Feed

Truck # B-04

Exposed filter was weighed and its pre-weight deducted to calculate the total mass of dust captured on the filter.

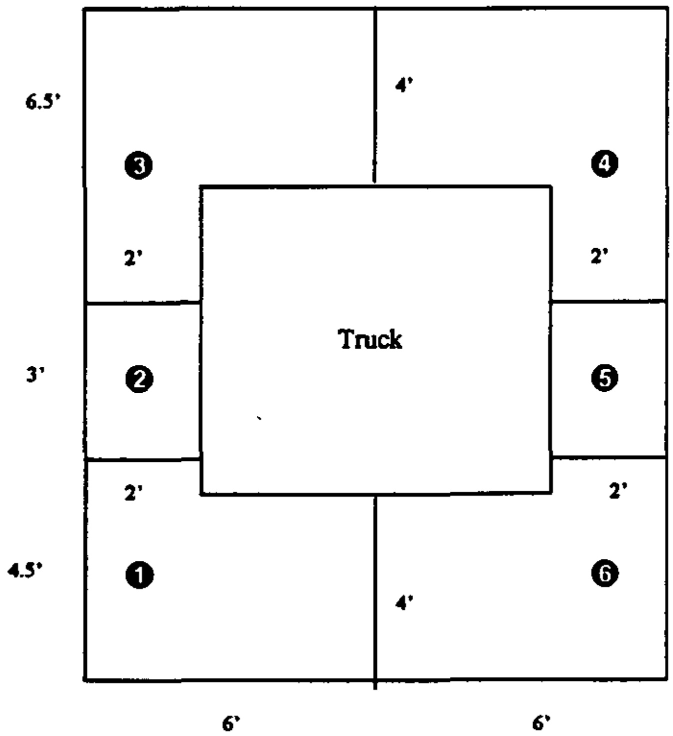
Mass of dust captured on filter (m), gm = 0.28

Mass of grain/feed dropped (M), lbs = 3.0

The emission factor was calculated by dividing the pounds of dust captured on the filter by the tons of grain/feed dropped.

$$\text{Emission Factor, (lbs / ton)} = \frac{m \times 2000}{M \times 454} = \frac{0.28 \times 2000}{3 \times 454} = 0.4061$$

Figure A-1: Area Associated With Each Grid Filter
(for Exit Dimensions of 12x14 ft)



For Protocol (C), (D) & (E): The area of the truck blocks the entrance or the exit hence:

Area ❶ , ft^2 = (4 x 6) + (0.5 x 2)   Area ❻ , ft^2 = (4 x 6) + (0.5 x 2)
Area ❷ , ft^2 = (3 x 2)   Area ❺, ft^2 = (3 x 2)
Area ❸, ft^2 = (4 x 6) + (2.5 x 2)   Area ❹, ft^2 = (4 x 6) + (2.5 x 2)

For Protocol (H): The Area of the truck does not block the entrance or exit hence:

Area ❶ , ft^2 = (4.5 x 6)   Area ❻ , ft^2 = (4.5 x 6)
Area ❷ , ft^2 = (3 x 6)   Area ❺, ft^2 = (3 x 6)
Area ❸, ft^2 = (6.5 x 6)   Area ❹, ft^2 = (6.5 x 6)

For Protocol (I): The Area of the truck does not block the entrance or exit hence:

Area ❶ , ft^2 = (4.5 x 12)
Area ❷ , ft^2 = (3 x 12)
Area ❸, ft^2 = (6.5 x 12)

APPENDIX B

Table B-1: Summary of Measured Emission Factors

Truck	TSP (lb/ton)				
#	Grain			Feed	
	Under	Under/Grid	Grid	Over	Grid
B-01			0.0027		
B-02			—		
B-03		0.0163			
B-04		0.0060			
B-05	0.0120				
B-06	0.0049				
B-07	0.0129				
B-08 to 11				0.0042	
B-12 to 14				0.0036	
B-15 to 17				0.0035	
B-18 to 21				0.0028	
B-22 to 25				0.0031	
B-26 to 29				0.0024	
B-30			0.0235		
C-01	0.0054				
C-02	0.0018				
C-03	0.0149				
C-04	0.0053				
C-05	0.0033				
C-06			0.0711		
C-07			0.0144		
C-08			0.0081		
C-09			0.0104		
C-10			0.0590		
C-11	0.0058				
C-12 to 15					0.0003
C-16 to 20					0.0015
C-21 to 24					0.0043
C-25 to 27					0.0040
C-28 to 30					0.0038
D-01	0.0156				
D-02	—				
D-03	0.0196				
D-04	0.0038				
D-05	0.0071				
D-06	0.0186				
D-07	0.0185				
D-08 to 11					0.0020
D-12 to 16					0.0035
D-17 to 19					0.0075
D-20 to 24					0.0381
Average	0.0100	0.0112	0.0270	0.0033	0.0072
Std. Dev.	0.0063	0.0073	0.0270	0.0006	0.0118

DATA SHEETS: FEED MILL B

Table B-2: Data Sheet for Truck# B-01

Data

Date/Time:	6-10-96/8:55
Sampling Protocol:	(C) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain %:	13.70
Grid Direction, deg:	90
Avg. wind direction, deg:	162
Avg. wind vel. (weather stn.), fpm:	130
Avg. wind vel. (anemometer), fpm:	52
Mass of grain handled, lb:	57880

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	150	0.25323	44	5.40
2	151	0.18865	44	5.40
3	152	0.13595	44	5.40
4	154	0.30675	44	5.10
5	155	0.37374	44	5.10
6	153	0.67018	44	5.10
background PM10	157	0.03242	44	80.00
background TSP	156	Error	44	80.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0376	0.0376	40	25	5.7799
2	0.0280	0.0280	40	6	1.0334
3	0.0202	0.0202	40	29	3.5997
4	0.0483	0.0483	40	29	8.1219
5	0.0588	0.0588	40	6	2.0474
6	0.1055	0.1055	40	25	15.2969
background PM10	0.0003				
background TSP	Error				

Total dust emitted, gm = 35.8793

Emission Factor (lbs/ton) = 0.0027

Table B-3: Data Sheet for Truck# B-02

Data

Date/Time:	6-10-96/9:15	
Sampling Protocol:	(C) Grid Sampling for Grain Unloading	
Grain Type:	Corn	
Moisture content of grain %:	14.03	
Grid Direction, deg:	90	
Avg. wind direction, deg:	350	(Wind blowing in opposite direction)
Avg. wind vel. (weather stn.), fpm:	99	
Avg. wind vel. (anemometer), fpm:	48	
Mass of grain handled, lb:	56240	

Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	163	0.02360	44	4.05
2	164	0.02126	44	4.10
3	165	0.02999	44	4.10
4	166	0.02179	44	3.95
5	167	0.02048	44	3.95
6	168	0.02284	44	4.00
background PM10	157	0.03242	44	80.00
background TSP	156	Error	44	80.00

Calculated Values

Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust emitted
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0047	0.0047	Error	25	Error
2	0.0042	0.0042	Error	6	Error
3	0.0059	0.0059	Error	29	Error
4	0.0044	0.0044	Error	29	Error
5	0.0042	0.0042	Error	6	Error
6	0.0046	0.0046	Error	25	Error
background PM10	0.0003				
background TSP	Error				

Total dust emitted, gm = Error

Emission Factor (lbs/ton) = Error

Table B-4: Data Sheet for Truck# B-03

Data

Date/Time:	6-10-96/9:25
Sampling Protocol:	(E) Under/Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	13.43
Grid direction, deg:	90
Avg. wind direction, deg:	115
Avg. wind vel. (weather stn.), fpm:	206
Avg. wind vel. (anemometer), fpm:	138
Mass of grain handled, lb:	56960

Grid Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	174	0.14185	44	6.90
2	173	0.09451	44	6.90
3	162	0.05462	44	6.90
4	177	0.05068	44	7.80
5	175	0.06582	44	7.80
6	176	0.10088	44	7.90
background PM10	157	0.03242	44	80.00
background TSP	156	Error	44	80.00

Under Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	181	0.21776	21	35.9456
8	180	0.08770	22	29.2114
9	178	0.15729	20	47.1659
10	179	0.46087	19	46.8674

Calculated Values

Grid Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0165	0.0165	187	25	15.0470
2	0.0110	0.0110	187	6	2.4062
3	0.0064	0.0064	187	29	6.7207
4	0.0052	0.0052	187	29	6.2363
5	0.0068	0.0068	187	6	1.6756
6	0.0102	0.0102	187	25	10.7009
background PM10	0.0003				
background TSP	Error				

Total mass of dust escaped from enclosure, gm	=	42.7867
Total mass of dust on filters from under the truck, gm	=	0.9236
Total mass of dust in bags from under the truck, gm	=	159.1903
Efficiency of cyclone pre-separator, %	=	99.4231
[1]Estimated mass of dust deposited in pre-separator, gm	=	8.0057
Total mass of dust, gm	=	210.9063
Emission Factor, lbs/ton	=	**0.0163**

Table B-5: Data Sheet for Truck# B-04

Data

Date/Time: 6-10-96/12:25
Sampling Protocol: (E) Under/Grid Sampling for Grain Unloading
GrainType: Corn
Moisture content of grain, %: 12.75
Grid direction, deg: 90
Avg. wind direction, deg: 35
Avg. wind vel. (weather stn.), fpm: 343
Avg. wind vel. (anemometer), fpm: 113
Mass of grain handled, lb: 56980

Grid Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	211	0.0314	44	9.40
2	213	0.0361	44	9.40
3	203	0.0260	44	9.40
4	210	0.0361	44	9.35
5	205	0.0280	44	9.35
6	204	0.0378	44	9.35
background PM10	185	0.0560	44	231.00
background TSP	183	0.0891	52	231.00

Under Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	209	0.0433	23	12.1779
8	208	0.0473	24	9.9710
9	207	0.0390	25	10.3079
10	206	0.0468	26	25.6758

Calculations

Grid Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0027	0.0024	197	25.00	3.1699
2	0.0031	0.0028	197	6.00	0.8848
3	0.0022	0.0020	197	29.00	2.9713
4	0.0031	0.0028	197	29.00	4.2787
5	0.0024	0.0021	197	6.00	0.6689
6	0.0032	0.0030	197	25.00	3.8868
background PM10	0.0002				
background TSP	0.0003				

Total mass of dust escaped from enclosure, gm	=	15.8605
Total mass of dust on filters from under the truck, gm	=	0.1764
Total mass of dust in bags from under the truck, gm	=	58.1325
Efficiency of cyclone pre-separator, %	=	99.6975
Estimated mass of dust deposited in pre-separator, gm	=	2.9154
Total mass of dust, gm	=	77.0849
Emission Factor, lbs/ton	=	**0.0060**

Table B-6: Data Sheet for Truck# B-05

Data

Date/Time:	6-10-96/12:50
Sampling protocol:	(A) Under the Truck Sampling for Grain Unloading
Grain Type:	Com
Moisture content of grain, %:	13.65
Mass of grain handled, lb:	57640

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	197	0.04933	27	19.254873
8	196	0.04826	28	36.37181
9	195	0.00000	29	28.628833
10	199	0.03267	30	30.692683

Calculated Values

Total mass of dust on filters, gm	=	0.1303
Total mass of dust in bags, gm	=	114.9482
Efficiency of cyclone pre-separator, %	=	99.8868
Estimated mass of dust deposited in pre-separator, gm	=	5.7539
Estimated mass of dust escaped from enclosure, gm	=	36.2497
Total mass of dust, gm	=	157.0821
Emission Factor, lbs/ton	**=**	**0.0120**

Table B-7: Data Sheet for Truck# B-06

Data

Date/Time: 6-10-96/13:20
Sampling protocol: (A) Under the Truck Sampling for Grain Unloading
Grain Type: Corn
Moisture content of grain, %: 13.23
Mass of grain handled, lb: 58060

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	200	0.03336	31	10.401333
8	198	0.00797	32	5.1298
9	218	0.03124	33	15.09461
10	201	0.03878	34	16.914023

Calculated Values

Total mass of dust on filters, gm	=	0.1114
Total mass of dust in bags, gm	=	47.5398
Efficiency of cyclone pre-separator, %	=	99.7663
Estimated mass of dust deposited in pre-separator, gm	=	2.3826
Estimated mass of dust escaped from enclosure, gm	=	15.0101
Total mass of dust, gm	=	65.0438
Emission Factor, lbs/ton	=	**0.0049**

Table B-8: Data Sheet for Truck# B-07

Data

Date/Time:	6-10-96/13:45
Sampling protocol:	(A) Under the Truck Sampling for Grain Unloading
Grain Type:	Com
Moisture content of grain, %:	12.98
Mass of grain handled, lb:	56700

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	226	0.03976	35	29.766247
8	225	0.04825	36	20.62514
9	224	0.06179	37	23.26151
10	223	0.04322	38	48.242853

Calculated Values

Total mass of dust on filters, gm	=	0.1930
Total mass of dust in bags, gm	=	121.8958
Efficiency of cyclone pre-separator, %	=	99.8419
Estimated mass of dust deposited in pre-separator, gm	=	6.1044
Estimated mass of dust escaped from enclosure, gm	=	38.4580
Total mass of dust, gm	=	166.6512
Emission Factor, lbs/ton	=	**0.0129**

Table B-9: Data Sheet for Truck# B-08 to B-11

Data

Date/Time:	6-11-96/6:35 to 6:55
Sampling protocol:	(G) Over the Truck Sampling for Feed Loading
Feed Type:	Ration# 6
Mass of feed handled, lb:	30000

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	273	0.0190033	39	5.120567
8	272	0.0660067	40	4.43409
9	271	0.03353	41	3.57096
10	270	0.03745	42	6.9106133

Calculated Values

Total mass of dust on filters, gm	=	0.1560
Total mass of dust in bags, gm	=	20.0362
Efficiency of cyclone pre-separator, %	=	99.2275
Estimated mass of dust deposited in pre-separator, gm	=	2.0192
Estimated mass of dust escaped from enclosure, gm	=	6.6634
Total mass of dust, gm	=	28.8749
Emission Factor, lbs/ton	=	**0.0042**

Table B-10: Data Sheet for Truck# B-12 to B-14

Data

Date/Time: 6-11-96/7:00 to 7:15

Sampling protocol: (G) Over the Truck Sampling for Feed Loading

Feed Type: Ration# 6,5,26

Mass of feed handled, lb: 18900

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	274	0.02252	43	3.30108
8	275	0.04254	44	1.91239
9	276	0.00663	45	2.8916733
10	277	0.03042	46	2.7105267

Calculated Values

Total mass of dust on filters, gm	=	0.1021
Total mass of dust in bags, gm	=	10.8157
Efficiency of cyclone pre-separator, %	=	99.0647
[1]Estimated mass of dust deposited in pre-separator, gm	=	1.0918
[1] Estimated mass of dust escaped from enclosure, gm	=	3.6029
Total mass of dust, gm	=	15.6124
Emission Factor, lbs/ton	=	**0.0036**

Table B-11: Data Sheet for Truck# B-15 to B-17

Data

Date/Time:	6-11-96/7:20 to 7:41
Sampling protocol:	(G) Over the Truck Sampling for Feed Loading
Feed Type:	Ration# 6
Mass of feed handled, lb:	24600

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	281	0.0218	47	2.4965
8	280	0.0308	48	3.4430
9	279	0.0195	49	3.7490
10	278	0.0376	50	4.0404

Calculated Values

Total mass of dust on filters, gm	=	0.1097
Total mass of dust in bags, gm	=	13.7289
Efficiency of cyclone pre-separator, %	=	99.2073
Estimated mass of dust deposited in pre-separator, gm	=	1.3839
Estimated mass of dust escaped from enclosure, gm	=	4.5667
Total mass of dust, gm	=	19.7892
Emission Factor, lbs/ton	=	**0.0035**

Table B-12: Data Sheet for Truck# B-18 to B-21

Data

Date/Time:	6-11-96/7:46 to 8:02
Sampling protocol:	(G) Over the Truck Sampling for Feed Loading
Feed Type:	Ration# 6
Mass of feed handled, lb:	32200

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	282	0.02155	51	3.96611
8	188	0.02884	52	2.63610
9	189	0.03957	53	4.10282
10	184	0.04961	54	3.53150

Calculated Values

Total mass of dust on filters, gm	=	0.1396
Total mass of dust in bags, gm	=	14.2365
Efficiency of cyclone pre-separator, %	=	99.0292
Estimated mass of dust deposited in pre-separator, gm	=	1.4376
Estimated mass of dust escaped from enclosure, gm	=	4.7441
Total mass of dust, gm	=	20.5578
Emission Factor, lbs/ton	=	**0.0028**

Table B-13: Data Sheet for Truck# B-22 to B-25

Data

Date/Time: 6-11-96/7:46 to 8:02
Sampling protocol: (G) Over the Truck Sampling for Feed Loading
Feed Type: Ration# 6,26,6,6
Mass of feed handled, lb: 24400

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	238	0.03438	55	3.00120
8	239	0.03426	56	2.61409
9	233	0.01872	57	3.16635
10	234	0.04468	58	3.17483

Calculated Values

Total mass of dust on filters, gm	=	0.1320
Total mass of dust in bags, gm	=	11.9565
Efficiency of cyclone pre-separator, %	=	98.9078
Estimated mass of dust deposited in pre-separator, gm	=	1.2089
Estimated mass of dust escaped from enclosure, gm	=	3.9892
Total mass of dust, gm	=	17.2866
Emission Factor, lbs/ton	=	**0.0031**

Table B-14: Data Sheet for Truck# B-26 to B-29

Data

Date/Time:	6-11-96/8:28 to 8:46
Sampling protocol:	(G) Over the Truck Sampling for Feed Loading
Feed Type:	Ration# 6
Mass of feed handled, lb:	26300

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	237	0.03803	59	3.06112
8	235	0.02861	60	2.20227
9	232	0.02160	61	2.15168
10	236	0.03920	62	2.46475

Calculated Values

Total mass of dust on filters, gm	=	0.1274
Total mass of dust in bags, gm	=	9.8798
Efficiency of cyclone pre-separator, %	=	98.7265
Estimated mass of dust deposited in pre-separator, gm	=	1.0007
Estimated mass of dust escaped from enclosure, gm	=	3.3024
Total mass of dust, gm	=	14.3104
Emission Factor, lbs/ton	=	**0.0024**

Table B-15: Data Sheet for Truck# B-30

Data

Date/Time:	6-11-96/11:30
Sampling Protocol:	(C) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain %:	13.90
Grid Direction, deg:	90
Avg. wind direction, deg:	108
Avg. wind vel. (weather stn.), fpm:	494
Avg. wind vel. (anemometer), fpm:	400
Mass of grain handled, lb:	58040

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	295	0.77465	44	8.20
2	293	0.55442	44	8.20
3	294	0.18728	44	8.20
4	296	0.02532	44	8.40
5	298	0.02265	44	8.40
6	297	0.02711	44	8.40
background PM10	284	0.03517	44	65.00
background TSP	285	0.04799	52	65.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0758	0.0753	470	25	205.4218
2	0.0543	0.0538	470	6	35.1914
3	0.0183	0.0178	470	29	56.4050
4	0.0024	0.0019	470	29	6.2165
5	0.0022	0.0017	470	6	1.1147
6	0.0026	0.0021	470	25	5.8360
background PM10	0.0004				
background TSP	0.0005				

Total dust emitted, gm = 310.1854

Emission Factor (lbs/ton) = 0.0235

Table B-16: Data Sheet for Truck# C-01

Data

Date/Time:	6-13-96/7:45
Sampling protocol:	(B) Under the Truck Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	11.28
Mass of grain handled, lb:	54820

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	325	0.12582	63	16.839313
8	326	0.11404	64	14.745563
9	327	0.13505	65	12.233317
10	328	0.15457	66	5.1155733

Calculated Values

Total mass of dust on filters, gm	=	0.5295
Total mass of dust in bags, gm	=	48.9338
Efficiency of cyclone pre-separator, %	=	98.9296
Estimated mass of dust deposited in pre-separator, gm	=	2.4732
Estimated mass of dust escaped from enclosure, gm	=	15.5809
Total mass of dust, gm	=	67.5173
Emission Factor, lbs/ton	**=**	**0.0054**

Table B-17: Data Sheet for Truck# C-02

Data

Date/Time:	6-13-96/8:10
Sampling protocol:	(B) Under the Truck Sampling for Grain Unloading
Grain Type:	Wheat mids
Moisture content of grain, %:	9.10
Mass of grain handled, lb:	56940

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	307	0.02619	67	3.42723
8	309	0.02610	68	4.84502
9	308	0.03315	69	3.17335
10	310	0.04266	70	5.28191

Calculated Values

Total mass of dust on filters, gm	=	0.1281
Total mass of dust in bags, gm	=	16.7275
Efficiency of cyclone pre-separator, %	=	99.2401
Estimated mass of dust deposited in pre-separator, gm	=	0.8428
Estimated mass of dust escaped from enclosure, gm	=	5.3095
Total mass of dust, gm	=	23.0079
Emission Factor, lbs/ton	**=**	**0.0018**

Table B-18: Data Sheet for Truck# C-03

Data

Date/Time: 6-13-96/8:50

Sampling protocol: (B) Under the Truck Sampling for Grain Unloading

Grain Type: Corn

Moisture content of grain, %: 13.53

Mass of grain handled, lb: 57600

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	304	0.09847	71	38.65026
8	305	0.23255	72	42.65232
9	306	0.15485	73	45.88533
10	313	0.39970	74	15.03558

Calculated Values

Total mass of dust on filters, gm	=	0.8856
Total mass of dust in bags, gm	=	142.2235
Efficiency of cyclone pre-separator, %	=	99.3812
Estimated mass of dust deposited in pre-separator, gm	=	7.1555
Estimated mass of dust escaped from enclosure, gm	=	45.0794
Total mass of dust, gm	=	195.3439
Emission Factor, lbs/ton	=	**0.0149**

Table B-19: Data Sheet for Truck# C-04

Data

Date/Time:	6-13-96/10:40
Sampling protocol:	(B) Under the Truck Sampling for Grain Unloading
Grain Type:	Com
Moisture content of grain, %:	14.23
Mass of grain handled, lb:	58220

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	251	0.05098	82	14.32524
8	283	0.10452	83	15.63982
9	286	0.04197	84	12.59741
10	287	0.03848	85	8.41880

Calculated Values

Total mass of dust on filters, gm	=	0.2359
Total mass of dust in bags, gm	=	50.9813
Efficiency of cyclone pre-separator, %	=	99.5393
Estimated mass of dust deposited in pre-separator, gm	=	2.5609
Estimated mass of dust escaped from enclosure, gm	=	16.1334
Total mass of dust, gm	=	69.9115
Emission Factor, lbs/ton	=	**0.0053**

Table B-20: Data Sheet for Truck# C-05

Data

Date/Time:	6-13-96/11:20
Sampling protocol:	(B) Under the Truck Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	13.70
Mass of grain handled, lb:	58220

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	363	0.02666	91	7.87901
8	338	0.03089	92	9.99297
9	339	0.02793	93	8.34273
10	340	0.02313	94	5.41380

Calculated Values

Total mass of dust on filters, gm	=	0.1086
Total mass of dust in bags, gm	=	31.6285
Efficiency of cyclone pre-separator, %	=	99.6578
Estimated mass of dust deposited in pre-separator, gm	=	1.5869
Estimated mass of dust escaped from enclosure, gm	=	9.9972
Total mass of dust, gm	=	43.3212
Emission Factor, lbs/ton	=	**0.0033**

Table B-21: Data Sheet for Truck# C-06

Data

Date/Time:	6-13-96/1:40
Sampling Protocol:	(D) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	14.15
Grid Direction, deg:	90
Avg. wind direction, deg:	127
Avg. wind vel. (weather stn.), fpm:	598
Avg. wind vel. (anemometer), fpm:	500
Mass of grain handled, lb:	55500

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	329	0.17788	43	19.35
2	336	0.11529	43	19.35
3	331	0.07800	43	19.35
4	333	0.40310	43	19.60
5	332	1.03000	43	19.60
6	330	2.27122	43	19.60
background PM10	291	0.04673	43	200.00
background TSP	346	0.14674	51	200.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0075	0.0070	478	25	46.0684
2	0.0049	0.0044	478	6	6.8854
3	0.0033	0.0028	478	29	21.2688
4	0.0169	0.0164	478	29	125.9289
5	0.0432	0.0426	478	6	67.8311
6	0.0952	0.0946	478	25	627.2712
background PM10	0.0002				
background TSP	0.0005				

Total dust emitted, gm	=	895.2537
Emission Factor (lbs/ton)	=	**0.0711**

Table B-22: Data Sheet for Truck# C-07

Data

Date/Time:	6-13-96/2:00
Sampling Protocol:	(D) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	13.70
Grid Direction, deg:	90
Avg. wind direction, deg:	133
Avg. wind vel. (weather stn.), fpm:	494
Avg. wind vel. (anemometer), fpm:	325
Mass of grain handled, lb:	56220

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	374	0.0651	43	20.00
2	362	0.0523	43	20.00
3	375	0.0420	43	20.00
4	378	0.0713	43	20.20
5	377	0.2414	43	20.20
6	376	0.6702	43	20.20
background PM10	291	0.0467	43	200.00
background TSP	346	0.1467	51	200.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0027	0.0022	361	25	11.0707
2	0.0021	0.0016	361	6	2.0149
3	0.0017	0.0012	361	29	7.2240
4	0.0029	0.0024	361	29	14.3387
5	0.0098	0.0093	361	6	11.5414
6	0.0272	0.0267	361	25	138.1532
background PM10	0.0002				
background TSP	0.0005				

Total dust emitted, gm	=	184.3429
Emission Factor (lbs/ton)	=	**0.0144**

Table B-23: Data Sheet for Truck# C-08

Data

Date/Time:	6-13-96/2:30
Sampling Protocol:	(D) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	14.78
Grid Direction, deg:	90
Avg. wind direction, deg:	144
Avg. wind vel. (weather stn.), fpm:	482
Avg. wind vel. (anemometer), fpm:	Error
Mass of grain handled, lb:	56540

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	366	0.09071	43	14.90
2	365	0.05178	43	14.90
3	364	0.02536	43	14.90
4	383	0.04412	43	15.00
5	381	0.13677	43	15.00
6	367	0.45777	43	15.00
background PM10	291	0.04673	43	200.00
background TSP	346	0.14674	51	200.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0050	0.0045	283	25	13.4232
2	0.0029	0.0023	283	6	1.6826
3	0.0014	0.0009	283	29	3.0838
4	0.0024	0.0019	283	29	6.6577
5	0.0075	0.0070	283	6	5.0401
6	0.0251	0.0246	283	25	73.8739
background PM10	0.0002				
background TSP	0.0005				

Total dust emitted, gm	=	103.7612
Emission Factor (lbs/ton)	=	**0.0081**

Table B-24: Data Sheet for Truck# C-09

Data

Date/Time:	6-13-96/2:50
Sampling Protocol:	(D) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	14.58
Grid Direction, deg:	90
Avg. wind direction, deg:	141
Avg. wind vel. (weather stn.), fpm:	862
Avg. wind vel. (anemometer), fpm:	500
Mass of grain handled, lb:	55520

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	384	0.07769	43	24.10
2	386	0.06692	43	24.10
3	385	0.04790	43	24.10
4	352	0.07780	43	24.40
5	382	0.13161	43	24.40
6	380	0.21750	43	24.40
background PM10	291	0.04673	43	200.00
background TSP	346	0.14674	51	200.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0026	0.0021	542	25	19.8008
2	0.0023	0.0018	542	6	3.9367
3	0.0016	0.0011	542	29	12.0701
4	0.0026	0.0021	542	29	22.9413
5	0.0044	0.0039	542	6	8.8198
6	0.0073	0.0068	542	25	63.8382
background PM10	0.0002				
background TSP	0.0005				

Total dust emitted, gm	=	131.4069
Emission Factor (lbs/ton)	=	**0.0104**

Table B-25: Data Sheet for Truck# C-10

Data

Date/Time:	6-13-96/3:20
Sampling Protocol:	(D) Grid Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	12.13
Grid Direction, deg:	90
Avg. wind direction, deg:	133
Avg. wind vel. (weather stn.), fpm:	884
Avg. wind vel. (anemometer), fpm:	663
Mass of grain handled, lb:	51440

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	395	0.14833	43	24.10
2	396	0.11761	43	24.10
3	394	0.08130	43	24.10
4	391	0.20386	43	24.40
5	392	0.59505	43	24.40
6	393	1.25507	43	24.40
background PM10	291	0.04673	43	200.00
background TSP	346	0.14674	51	200.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0051	0.0045	647	25	50.1495
2	0.0040	0.0035	647	6	9.2652
3	0.0028	0.0023	647	29	28.9468
4	0.0069	0.0064	647	29	82.3063
5	0.0200	0.0195	647	6	52.3188
6	0.0422	0.0417	647	25	466.0844
background PM10	0.0002				
background TSP	0.0005				

Total dust emitted, gm	=	689.0708
Emission Factor (lbs/ton)	=	**0.0590**

Table B-26: Data Sheet for Truck# C-11

Data

Date/Time:	6-13-96/16:00
Sampling protocol:	(B) Under the Truck Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	12.50
Mass of grain handled, lb:	49030

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	343	0.05769	95	12.86837
8	342	0.04860	96	14.91221
9	341	0.04890	97	7.95618
10	344	0.05720	98	11.33761

Calculated Values

Total mass of dust on filters, gm	=	0.2124
Total mass of dust in bags, gm	=	47.0744
Efficiency of cyclone pre-separator, %	=	99.5508
Estimated mass of dust deposited in pre-separator, gm	=	2.3643
Estimated mass of dust escaped from enclosure, gm	=	14.8953
Total mass of dust, gm	=	64.5464
Emission Factor, lbs/ton	**=**	**0.0058**

Table B-27: Data Sheet for Truck# C-12 to 15

Data

Date/Time:	6-14-96/9:30 to 10:00
Sampling protocol:	(I) Grid Sampling for Feed Loading
Feed Type:	Ration# 5
Grid direction, deg:	90
Avg. wind direction, deg:	77
Avg. wind vel. (weather stn.), fpm:	367
Avg. wind vel. (anemometer), fpm:	275
Mass of feed handled, lb:	93800

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
Downwind	443	0.07432	43	27.00
2	430	0.05575	43	27.00
3	431	0.08260	43	27.00
Upwind	429	0.09428	43	27.10
5	446	0.05386	43	27.10
6	432	0.07032	43	27.10

Calculated Values

Sampler #	Loading rate gm/m3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
Downwind	0.0023	0.0001	358	54	0.7938
2	0.0017	0.0000	358	36	0.0000
3	0.0025	0.0003	358	66	5.5148
Upwind	0.0029				
5	0.0016				
6	0.0021				

Total dust emitted, gm	=	6.3086
Emission Factor (lbs/ton)	=	**0.0003**

Table B-28: Data Sheet for Truck# C-16 to 20

Data

Date/Time:	6-14-96/10:50 to 11:35
Sampling protocol:	(I) Grid Sampling for Feed Loading
Feed Type:	Ration# 5
Grid direction, deg:	90
Avg. wind direction, deg:	117
Avg. wind vel. (weather stn.), fpm:	294
Avg. wind vel. (anemometer), fpm:	460
Mass of feed handled, lb:	145810

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
Downwind	428	0.11830	43	43.50
2	427	0.12038	43	43.50
3	426	0.11750	43	43.50
Upwind	401	0.05656	43	43.50
5	402	0.07049	43	43.50
6	414	0.07652	43	43.50

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
Downwind	0.0022	0.0010	262	54	16.5950
2	0.0023	0.0010	262	36	11.5188
3	0.0022	0.0009	262	66	19.9611
Upwind	0.0011				
5	0.0013				
6	0.0014				

Total dust emitted, gm	=	**48.0748**
Emission Factor (lbs/ton)	=	**0.0015**

Table B-29: Data Sheet for Truck# C-21 to 24

Data

Date/Time:	6-14-96/12:05 to 12:40
Sampling protocol:	(I) Grid Sampling for Feed Loading
Feed Type:	Ration# 6
Grid direction, deg:	90
Avg. wind direction, deg:	124
Avg. wind vel. (weather stn.), fpm:	548
Avg. wind vel. (anemometer), fpm:	550
Mass of feed handled, lb:	99130

Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
Downwind	403	0.10832	43	22.20
2	404	0.10557	43	22.20
3	405	0.07103	43	22.20
Upwind	423	0.03414	43	22.20
5	424	0.03149	43	22.20
6	425	0.03493	43	22.20

Calculated Values

Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust emitted
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
Downwind	0.0040	0.0028	454	54	42.6739
2	0.0039	0.0027	454	36	27.4033
3	0.0026	0.0014	454	66	26.1541
Upwind	0.0013				
5	0.0012				
6	0.0013				

Total dust emitted, gm	=	96.2313
Emission Factor (lbs/ton)	=	**0.0043**

Table B-30: Data Sheet for Truck# C-25 to 27

Data

Date/Time:	6-14-96/13:05 to 13:40
Sampling protocol:	(I) Grid Sampling for Feed Loading
Feed Type:	Ration# 5
Grid direction, deg:	90
Avg. wind direction, deg:	120
Avg. wind vel. (weather stn.), fpm:	652
Avg. wind vel. (anemometer), fpm:	325
Mass of feed handled, lb:	116310

Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
Downwind	422	0.12324	43	35.80
2	419	0.07494	43	35.80
3	418	0.06295	43	35.80
Upwind	415	0.03523	43	35.80
5	416	0.03512	43	35.80
6	417	0.03549	43	35.80

Calculated Values

Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust emitted
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
Downwind	0.0028	0.0020	565	54	62.3719
2	0.0017	0.0009	565	36	18.7484
3	0.0014	0.0006	565	66	23.9779
Upwind	0.0008				
5	0.0008				
6	0.0008				

Total dust emitted, gm	=	105.0982
Emission Factor (lbs/ton)	=	**0.0040**

Table B-31: Data Sheet for Truck# C-28 to 30

Data

Date/Time:	6-14-96/13:45 to 14:45
Sampling protocol:	(I) Grid Sampling for Feed Loading
Feed Type:	Ration# 6
Grid direction, deg:	90
Avg. wind direction, deg:	117
Avg. wind vel. (weather stn.), fpm:	535
Avg. wind vel. (anemometer), fpm:	300
Mass of feed handled, lb:	90670

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
Downwind	454	0.1146	43	33.00
2	407	0.0835	43	33.00
3	453	0.0606	43	33.00
Upwind	451	0.0368	43	33.00
5	450	0.0371	43	33.00
6	452	0.0435	43	33.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
Downwind	0.0029	0.0019	477	54	45.1708
2	0.0021	0.0011	477	36	17.7168
3	0.0015	0.0005	477	66	15.6868
Upwind	0.0009				
5	0.0009				
6	0.0011				

Total dust emitted, gm = 78.5745
Emission Factor (lbs/ton) = 0.0038

DATA SHEETS: FEED MILL D

Table B-32: Data Sheet for Truck# D-01

Data

Date/Time:	6-17-96/8:55
Sampling protocol:	(A) Under the Truck Sampling for Grain Unloading
Grain Type:	Milo
Moisture content of grain, %:	13.65
Mass of grain handled, lb:	54460

Sampler	Filter	Dust on filter	Bag	Dust in bag
#	#	gm	#	gm
7	458	0.2032	99	35.8138
8	476	0.1958	100	31.1918
9	501	0.2222	101	37.6521
10	499	0.2221	102	36.1815

Calculated Values

Total mass of dust on filters, gm	=	0.8433
Total mass of dust in bags, gm	=	140.8391
Efficiency of cyclone pre-separator, %	=	99.4048
Estimated mass of dust deposited in pre-separator, gm	=	7.0841
Estimated mass of dust escaped from enclosure, gm	=	44.6300
Total mass of dust, gm	=	193.3965
Emission Factor, lbs/ton	=	**0.0156**

Table B-33: Data Sheet for Truck# D-03

Data

Date/Time: 6-17-96/9:45

Sampling protocol: (A) Under the Truck Sampling for Grain Unloading

Grain Type: Corn

Moisture content of grain, %: 13.88

Mass of grain handled, lb: 64460

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	479	0.08047	107	49.91898
8	489	0.09081	108	58.122723
9	490	0.10171	109	67.43761
10	491	0.15759	110	34.42921

Calculated Values

Total mass of dust on filters, gm	=	0.4306
Total mass of dust in bags, gm	=	209.9085
Efficiency of cyclone pre-separator, %	=	99.7953
Estimated mass of dust deposited in pre-separator, gm	=	10.5170
Estimated mass of dust escaped from enclosure, gm	=	66.2568
Total mass of dust, gm	=	287.1129
Emission Factor, lbs/ton	=	**0.0196**

Table B-34: Data Sheet for Truck# D-04

Data

Date/Time:	6-17-96/10:05
Sampling protocol:	(A) Under the Truck Sampling for Grain Unloading
Grain Type:	Milo
Moisture content of grain, %:	13.35
Mass of grain handled, lb:	53050

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	493	0.04684	111	6.0959167
8	492	0.04570	112	4.2252533
9	495	0.05643	113	7.0464267
10	494	0.13338	114	15.900117

Calculated Values

Total mass of dust on filters, gm	=	0.2824
Total mass of dust in bags, gm	=	33.2677
Efficiency of cyclone pre-separator, %	=	99.1584
Estimated mass of dust deposited in pre-separator, gm	=	1.6775
Estimated mass of dust escaped from enclosure, gm	=	10.5683
Total mass of dust, gm	=	45.7958
Emission Factor, lbs/ton	**=**	**0.0038**

Table B-35: Data Sheet for Truck# D-05

Data

Date/Time:	6-17-96/11:25
Sampling protocol:	(A) Under the Truck Sampling for Grain Unloading
Grain Type:	Milo
Moisture content of grain, %:	13.30
Mass of grain handled, lb:	53740

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	510	0.08337	115	10.906067
8	511	0.11987	116	15.887603
9	512	0.11030	117	16.98939
10	513	0.14785	118	19.505747

Calculated Values

Total mass of dust on filters, gm	=	0.4614
Total mass of dust in bags, gm	=	63.2888
Efficiency of cyclone pre-separator, %	=	99.2763
Estimated mass of dust deposited in pre-separator, gm	=	3.1875
Estimated mass of dust escaped from enclosure, gm	=	20.0813
Total mass of dust, gm	=	87.0190
Emission Factor, lbs/ton	=	**0.0071**

Table B-36: Data Sheet for Truck# D-06

Data

Date/Time:	6-17-96/11:45
Sampling protocol:	(A) Under the Truck Sampling for Grain Unloading
Grain Type:	Corn
Moisture content of grain, %:	13.30
Mass of grain handled, lb:	59860

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	509	0.05309	119	47.06368
8	508	0.06092	120	54.06031
9	506	0.04829	121	42.942573
10	507	0.06824	122	40.88214

Calculated Values

Total mass of dust on filters, gm	=	0.2305
Total mass of dust in bags, gm	=	184.9487
Efficiency of cyclone pre-separator, %	=	99.8755
Estimated mass of dust deposited in pre-separator, gm	=	9.2590
Estimated mass of dust escaped from enclosure, gm	=	58.3315
Total mass of dust, gm	=	252.7697
Emission Factor, lbs/ton	=	**0.0186**

Table B-37: Data Sheet for Truck# D-07

Data

Date/Time: 6-17-96/11:45
Sampling protocol: (A) Under the Truck Sampling for Grain Unloading
Grain Type: Corn
Moisture content of grain, %: 13.48
Mass of grain handled, lb: 61520

Sampler #	Filter #	Dust on filter gm	Bag #	Dust in bag gm
7	502	0.05896	127	35.749657
8	503	0.07510	128	51.32344
9	505	0.05981	129	52.183473
10	504	0.07924	130	49.636337

Calculated Values

Total mass of dust on filters, gm	=	0.2731
Total mass of dust in bags, gm	=	188.8929
Efficiency of cyclone pre-separator, %	=	99.8556
Estimated mass of dust deposited in pre-separator, gm	=	9.4583
Estimated mass of dust escaped from enclosure, gm	=	59.5873
Total mass of dust, gm	=	258.2116
Emission Factor, lbs/ton	=	**0.0185**

Table B-38: Data Sheet for Truck# D-08 to D-11

Data

Date/Time:	6-18-96/6:45 - 7:15
Sampling Protocol:	(H) Grid Sampling for Feed Loading
Feed Type:	Ration# SI,4,5,SI
Grid Direction, deg:	180
Avg. wind direction, deg:	196
Avg. wind vel. (weather stn.), fpm:	202
Avg. wind vel. (anemometer), fpm:	200
Mass of grain handled, lb:	44200

Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	537	0.09888	43	33.00
2	473	0.08915	43	33.00
3	498	0.06686	43	33.00
4	500	0.07563	43	33.30
5	470	0.06957	43	33.30
6	562	0.07452	43	33.30
background PM10	566	0.00457	43	33.00
background TSP	549	0.06124	51	33.00

Calculated Values

Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust emitted
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0025	0.0012	194	27	5.7600
2	0.0022	0.0009	194	18	3.0491
3	0.0017	0.0004	194	39	2.6815
4	0.0019	0.0006	194	39	4.1439
5	0.0017	0.0004	194	18	1.4200
6	0.0018	0.0006	194	27	2.7327
background PM10	0.0001				
background TSP	0.0013				

Total dust emitted, gm = 19.7874
Emission Factor (lbs/ton) = 0.0020

Table B-39: Data Sheet for Truck# D-12 to D-16

Data

Date/Time:	6-18-96/7:25 - 8:30
Sampling Protocol:	(H) Grid Sampling for Feed Loading
Feed Type:	Ration# 2,4,3,1,4
Grid Direction, deg:	180
Avg. wind direction, deg:	243
Avg. wind vel. (weather stn.), fpm:	654
Avg. wind vel. (anemometer), fpm:	215
Mass of grain handled, lb:	27780

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	542	0.07106	43	60.30
2	544	0.06167	43	60.30
3	546	0.05507	43	60.30
4	547	0.07783	43	61.30
5	545	0.09339	43	61.30
6	541	0.09219	43	61.30
background PM10	567	0.01153	43	61.00
background TSP	548	0.06512	51	61.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0010	0.0002	297	27	3.1291
2	0.0008	0.0001	297	18	0.9199
3	0.0007	0.0000	297	39	0.2157
4	0.0010	0.0003	297	39	6.1015
5	0.0013	0.0005	297	18	4.7496
6	0.0012	0.0005	297	27	6.9007
background PM10	0.0002				
background TSP	0.0007				

Total dust emitted, gm = 22.0164

Emission Factor (lbs/ton) = 0.0035

Table B-40: Data Sheet for Truck# D-17 to D-19

Data

Date/Time:	6-18-96/8:35 - 9:25
Sampling Protocol:	(H) Grid Sampling for Feed Loading
Feed Type:	Ration# S1,S1,4
Grid Direction, deg:	180
Avg. wind direction, deg:	230
Avg. wind vel. (weather stn.), fpm:	1097
Avg. wind vel. (anemometer), fpm:	225
Mass of grain handled, lb:	40620

Sampler	Filter	Dust on filter	Sampling rate	Sampling time
#	#	gm	cfm	min
1	517	0.1488	43	28.80
2	516	0.0893	43	28.80
3	551	0.0706	43	28.80
4	576	0.0521	43	28.70
5	575	0.0377	43	28.70
6	574	0.0438	43	28.70
background PM10	569	0.0070	43	29.00
background TSP	573	0.0602	51	29.00

Calculated Values

Sampler	Loading rate	Corrected loading	Wind velocity	Sampling	Dust emitted
#	gm/m^3	rate (gm/m^3)	dir. X (fpm)	area (ft^2)	gm
1	0.0042	0.0028	705	27	43.5385
2	0.0025	0.0011	705	18	11.4599
3	0.0020	0.0006	705	39	12.8958
4	0.0015	0.0001	705	39	1.2082
5	0.0011	0.0000	705	18	0.0000
6	0.0013	0.0000	705	27	0.0000
background PM10	0.0002				
background TSP	0.0014				

Total dust emitted, gm	=	69.1025
Emission Factor (lbs/ton)	**=**	**0.0075**

Table B-41: Data Sheet for Truck# D-20 to D-24

Data

Date/Time:	6-18-96/9:50 - 11:00
Sampling Protocol:	(H) Grid Sampling for Feed Loading
Feed Type:	Ration# 5,4,1,5,2
Grid Direction, deg:	180
Avg. wind direction, deg:	228
Avg. wind vel. (weather stn.), fpm:	1229
Avg. wind vel. (anemometer), fpm:	510
Mass of grain handled, lb:	46890

Sampler #	Filter #	Dust on filter gm	Sampling rate cfm	Sampling time min
1	591	0.24869	43	55.70
2	589	0.22716	43	55.70
3	590	0.13443	43	55.70
4	571	0.15371	43	55.70
5	570	0.19959	43	55.70
6	572	0.25265	43	55.70
background PM10	582	0.01912	43	56.00
background TSP	580	0.07992	51	56.00

Calculated Values

Sampler #	Loading rate gm/m^3	Corrected loading rate (gm/m^3)	Wind velocity dir. X (fpm)	Sampling area (ft^2)	Dust emitted gm
1	0.0037	0.0027	822	27	93.8087
2	0.0033	0.0024	822	18	55.1276
3	0.0020	0.0010	822	39	50.2767
4	0.0023	0.0013	822	39	64.6569
5	0.0029	0.0020	822	18	45.6356
6	0.0037	0.0027	822	27	95.8535
background PM10	0.0003				
background TSP	0.0010				

Total dust emitted, gm	=	405.3590
Emission Factor (lbs/ton)	=	**0.0381**

Note

Large leafy material deposited on grid samplers.

APPENDIX C

DETERMINING PM-10 CONCENTRATIONS USING THE COULTER MULTISIZER II[1]

Typically, PM-10 is measured with a sampling system designed to separate particulate matter larger than 10 micrometers aerodynamic diameter (AD) allowing the PM-10 to penetrate to the filter. An alternative method of measuring PM-10 is to measure the concentration of total suspended particulate (TSP), perform a particle size distribution (PSD) on the captured particulate, and multiply the TSP concentration by the fraction less 10 micrometers obtained from the PSD. We refer to this process of determining PM-10 as the TSP/Coulter method. Raina and Parnell (1995) compared the two methods of determining PM-10 concentrations using results from sampling cattle feed yards with Wedding PM-10 samplers side by side with High Volume (HiVol) samplers and found that there was no difference.

In this study, particle size distributions were determined using the Coulter Counter Multisizer II. This instrument is a variable multichannel particle size analyzer which uses the Coulter electrical impedance method to measure particle size distributions. The range of particle sizes included in a Coulter Counter PSD is dependent upon the size of the aperture tube. We used a 100 μm aperture tube. Our results provided a measure of the volume percent of particulate less than 100 μm with an increased accuracy in the range of 4 to 40% of the aperture size. This process involves dispersing particulate in an electrolyte, moving the electrolyte with dust particles through the aperture tube opening, detecting the volume of the particle, and recording the number of particles in each range. We used 64 ranges from 0 to 100 μm.

The scientific basis for the Coulter Counter is as follows:

- A constant current exists between platinum electrodes inside and outside the aperture tube. This current passes through the aperture tube opening.
- A constant volume rate of flow of electrolyte (with entrained particulate) is moved through the aperture.
- As a particle is conveyed through the opening, it disrupts the current flow. This disruption is detected and is proportional to the volume of the particle.
- All particles are assumed to be spherical. The diameter of each particle is calculated from the volume measurement and it is counted and recorded in the range corresponding to its size.

We typically use 64 channels and count 150,000 to 300,000 particles for each PSD. Our choice of electrolyte is Lithium Chloride/Methanol. The electrolyte is prepared by sequential filtration to remove all particulate larger than 0.2 μm. The particle size distributions are represented graphically as a percentage of the total volume in each channel. Each channel has a corresponding size range.

[1] This appendix was prepared by Michael A. Demny, Graduate Research Assistant, Anthony M. Tacker, Laboratory Technician, and Elena Garza, Student Worker.

We use the Coulter Counter PSD results as a measure of the mass of particulate in each size range by assuming that the particle density of the particulate in each size range is constant and equal. The particle density of organic dust is typically 1.4 to 1.5 grams per cubic centimeter (Parnell et al., 1986).

The Coulter Counter Multisizer results are a measure of the mass percent versus spherical particle size. To compare these results to the measured PM-10 concentrations using a sampler that pre-separates particulate larger than 10 µm, the particle size ranges must be converted to aerodynamic diameter. The spherical diameters are converted to aerodynamic diameters with the following equation:

$$D_a = (s)^{1/2} \cdot D_s \qquad \text{(C-1)}$$

where,

D_a	=	aerodynamic diameter
s	=	specific gravity of the particle; (1.5 g/cm^3 for corn dust)
D_s	=	spherical particle size

A 10 micron aerodynamic diameter particle with a specific gravity of 1.5 g/cm^3 will have an equivalent spherical diameter of 8.16 µm. This equivalent spherical diameter was used to obtain the cumulative mass percentage of particles with an aerodynamic diameter of 10 microns or less (PM-10).

The procedure for obtaining an accurate particle size distribution is dependent upon cleanliness and proper sample preparation. The laboratory protocol is as follows:

Cleaning Protocol

Beakers

- Sparingly (approximately 2 grams) apply the Alconox cleaning agent into the specified contaminated beakers along with tap water.
- Use plastic brush to thoroughly scrub each beaker and after scrubbing, rinse the beaker out with tap water to remove all remnants from cleaning agent.
- Rinse the beakers generously with distilled water. This removes any contaminated particles that remain from the tap water rinsing.
- Rinse the beakers generously with methanol. This is the final step taken to insure that all contaminated particles are removed from the beakers.

Nylon Screen (100 openings)

- Pour approximately 60 milliliters of Coulter Cleanse into ultrasonic device. (Approximately 90 milliliters of tap water can be added to dilute the cleaning agent)
- Place the contaminated screen into the ultrasonic device and activate for 5 minutes. This process loosens the particles which may have wedged into the fibers.
- Remove screen from ultrasonic device and scrub screen with plastic brush, then run screen under tap water to extract the contaminated particles.
- Rinse screen generously with distilled water on both sides.

- Rinse screen a final time with methanol.

Syringe

- Pour approximately 30 milliliters of Coulter Cleanse into ultrasonic device. (Approximately 20 milliliters of tap water can be added to dilute the cleaning agent)
- Place the contaminated syringe into the ultrasonic device and activate for 3 minutes.
- When the ultrasonic is through, take syringe and draw up the cleaning solution into the syringe and discharge solution repeatedly to allow the cleaning solution to flush out particles that may be lodged in the nose of the syringe.
- Take apart the syringe and rinse thoroughly with distilled water.
- Rinse each part with methanol and reassemble syringe.
- Pour approximately 10 milliliters of methanol into a clean beaker and flush out the nose of the syringe.

Preparation of Sample

- Place exposed filter and fold it over once then place over cutting block.
- Using a size 15 cutting instrument (with a diameter of 22.23 mm) cut three samples from each filter. These are identified as wafers.
- Place wafers into paper sleeves and place the sleeves into small envelopes labeled with the filter information.
- To prepare, take the three wafers from the specified filter and place them into a sterilized beaker.
- Pour approximately 25 milliliters of electrolyte (5% lithium chloride/methanol solution) into beaker with wafers.
- Place beaker into ultrasonic device for 2 minutes.
- Remove beaker from ultrasonic device and pour contents through the screen (100) into another sterilized beaker. This process is repeated until the sample has been filtered three times.
- When the final preparation is complete a clean stirring pill is placed in the beaker with the sample and the beaker is set on the magnetic stirrer until it is time for a sample to be drawn from it.

Once the sample has been prepared, it can be processed through the Coulter Counter. The entire process takes approximately 10 minutes to complete. After the Coulter has finished its analysis, the output is sent to a computer and filed on a disk for future reference. The graphical output of the Coulter Multisizer II resembles the following example in **Figure C-1**.

Along with the graphical output, the Coulter Multisizer II also generates a cumulative listing of the volume percent of particles in each channel. **Table C-1** is an example of a partial listing of the cumulative volume percent for a sample PSD. An actual listing includes only the spherical diameter, but we have included the aerodynamic diameter to illustrate the relationship between them. To obtain a reliable percentage of PM-10, it is imperative to reference the cumulative listing using the aerodynamic diameter. In the analyses of the PSDs from this research, we obtained a cumulative percent ending at channel 28, where the aerodynamic diameter is equal to 10.18 μm.

Figure C-1: Graphical Output From Sample PSD

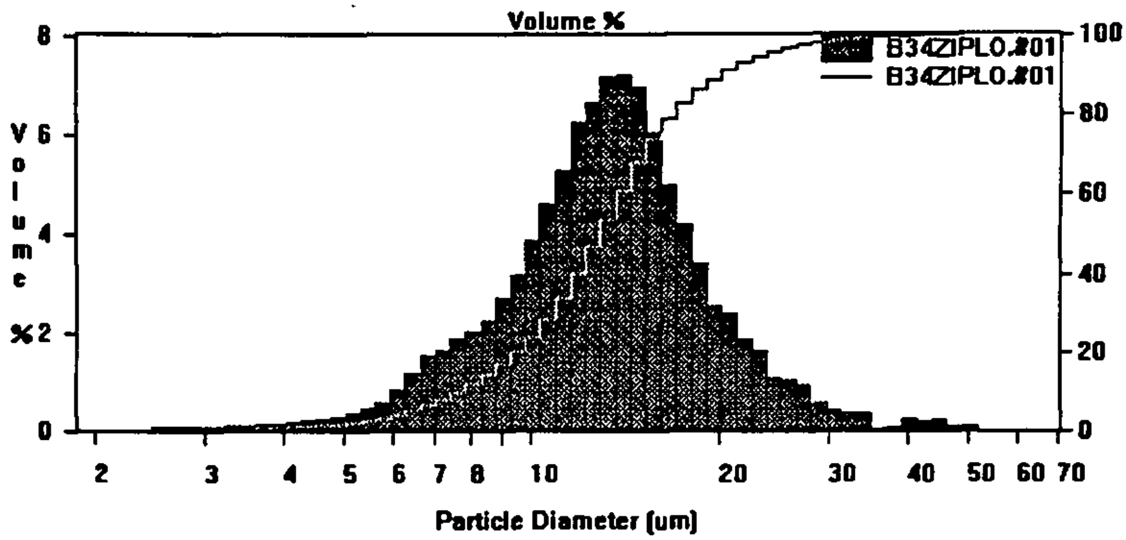


Table C-1: Partial Cumulative Listing From Sample PSD

Channels (#)	Spherical Particle Diameter[†] (μm)	Aerodynamic Particle Diameter[††] (μm)	Cumulative < Volume (%)
24	6.66	8.16	6.46
25	7.04	8.62	8.05
26	7.44	9.11	9.90
27	7.87	9.64	11.90
28	8.31	10.18	14.12
29	8.79	10.77	16.82
30	9.29	11.38	19.96
31	9.82	12.03	23.80
32	10.38	12.71	28.35
33	10.97	13.44	33.60
34	11.60	14.21	39.81
35	12.26	15.01	46.43
36	12.96	15.87	53.59
37	13.69	16.77	60.79
38	14.48	17.73	67.71
39	15.30	18.74	73.71

† These values represent the lower end of the range for particle size in the specified channel.

†† The aerodynamic diameters were calculated using equation C-1 with a specific gravity of 1.5 g/cm^3

The results of the particle size analyses on exposed filters obtained during the sampling at Feed Mills B, C and D are in **Tables C-2, C-3, C-4 and C-5**.

Table C-2: Percent PM-10 for "Under the Truck" Sampling (Grain Unloading - Corn)

Truck #	Zip lock or Filter #	PM-10 %	Weighted Avg.* % PM-10
B03	Zip lock #20 Filter #178	11.6 69.77	11.94
B04	Zip lock #26 Filter #206	9.87 25.36	9.92
B05	Zip lock #28 Filter #196	11.79 29.29	11.81
B06	Zip lock #34 Filter #201	12.74 33.52	12.79
B07	Zip lock #38 Filter #223	13.17 31.82	13.20
C01	Zip lock #63 Filter #325	10.65 45.96	11.03
C03	Zip lock #73 Filter #306	9.91 93.2	10.43
C04	Zip lock #83 Filter #283	11.66 73.99	11.95
C05	Zip lock #92 Filter #338	10.7 35.48	10.78
C11	Zip lock #96 Filter #342	16.67 67.91	16.90
D03	Zip lock #109 Filter #490	14.81 69.13	14.92
D06	Zip lock #120 Filter #508	10.96 56.11	11.01
D07	Zip lock #129 Filter #504	13.21 71.4	13.29
Average **Std. Dev.**			12.30 1.94

*Weighted Avg. %PM-10 = [(Dust in Bag x %PM-10 in Bag)+(Dust on Filter x %PM-10 on Filter)] + [Dust in Bag + Dust on Filter]

Table C-3: Percent PM-10 for Grid Sampling (Grain Unloading - Corn)

Truck #	Filter #	PM-10 %
B01	Filter #153	19.38
B02	Filter #168	16.33
B30	Filter #295	16.52
C06	Filter #330	9.97
C07	Filter #376	14.04
C08	Filter #367	15.35
C09	Filter #380	18.15
C10	Filter #393	15.16
Average **Std. Dev.**		15.61 2.84

Table C-4: Percent PM-10 for "Over the Truck" Sampling (Feed Loading)

Truck #	Zip lock or Filter #	PM-10 %	Weighted Avg.* % PM-10
B0811	Zip lock #42 Filter #270	10.17 26.73	10.30
B1214	Zip lock #43 Filter #274	4.4 15.58	4.51
B1517	Zip lock #50 Filter #278	8.01 36.55	8.24
B1821	Zip lock #53 Filter #189	7.35 35.02	7.62
B2225	Zip lock #58 Filter #234	4.1 50.07	4.60
B2629	Zip lock #59 Filter #237	3.1 20.63	3.12
Average Std. Dev.			6.40 2.74

*Weighted Avg. %PM-10 = [(Dust in Bag x %PM-10 in Bag)+(Dust on Filter x %PM-10 on Filter)] ÷ [Dust in Bag + Dust on Filter]

Table C-5: Percent PM-10 for Grid Sampling (Feed Loading)

Truck #	Filter #	PM-10 %
C1215	Filter #431	31.82
C1620	Filter #426	38.75
C2124	Filter #405	30.08
C2527	Filter #418	33.63
C2830	Filter #453	30.14
D0811	Filter #537	24.01
D1216	Filter #541	44.13
D1719	Filter #517	30.61
D2024	Filter #572	26.67
Average Std. Dev.		32.20 6.09

Table C-6: Percent PM-10 for "Under the Truck" Sampling (Grain Unloading - Milo)

Truck #	Zip lock or Filter #	PM-10 %	Weighted Avg.* % PM-10
D01	Zip lock #101 Filter #501	14.27 74.54	14.53
D04	Zip lock #114 Filter #494	10.60 87.23	11.24
D05	Zip lock #118 Filter #513	15.80 87.05	16.32
Average Std. Dev.			14.03 2.58

*Weighted Avg. %PM-10 = [(Dust in Bag x %PM-10 in Bag)+(Dust on Filter x %PM-10 on Filter)] + [Dust in Bag + Dust on Filter]

APPENDIX D

DESIGN CONSIDERATIONS FOR THE GRID SAMPLING STRUCTURE[2]

One of the methods we used to measure the emission factor from feed mills associated with feed yards was to measure the concentration of total suspended particulate at the downwind exit of the sheds enclosing the grain unloading and the feed loading operations, multiplying this concentration by the volume of sampled air to determine the mass of particulate matter emitted during the unloading or loading time period and dividing this mass by the tons of grain unloaded or loaded, respectively. We referred to this procedure as "grid sampling" in the report. Drs. Parnell and Shaw visited a number of feed mills prior to designing the grid sampling system and made the following observations:

- The trucks delivering grain to the feed mill were typically not enclosed by the shed. (A portion of the cab or trailer was outside the shed during the unloading operation.) Hence, our grid sampling system would have to measure the concentration in the open area on either side of the truck and the shed wall.
- The concentrations of dust varied with height. It was deemed necessary to have concentration measurements at different heights in the doorway. We chose to sample at 3, 6 and 9 feet above the ground.
- The truck obstructed the doorway. We chose to calculate our volume rate of flow by accounting for the obstructed area.

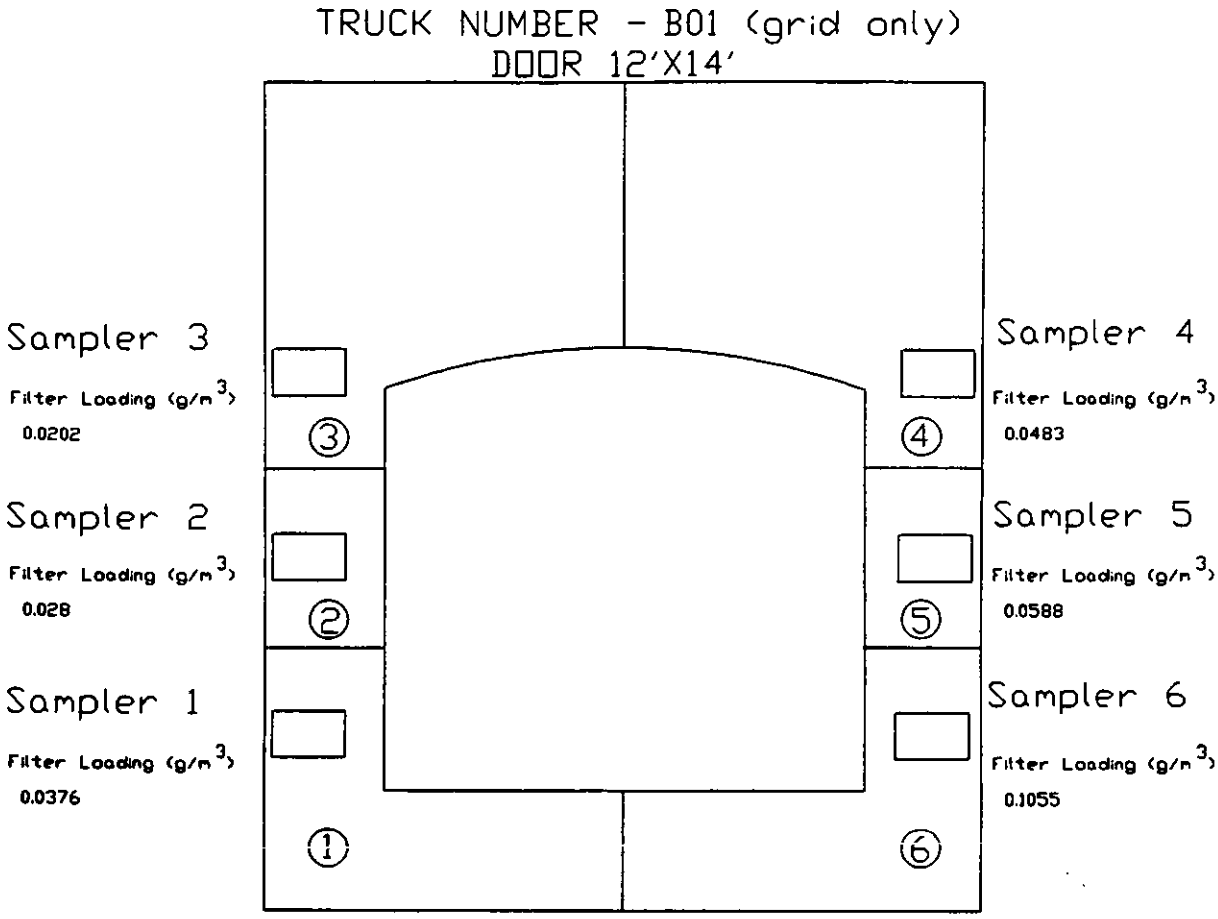
Prior to constructing the grid structure, it was anticipated that exit doors with different heights and widths would be encountered at the selected feed mills' grain receiving and feed loading sheds. Therefore, to accommodate at any situation the grid required a flexible design. The major concern dealt with the limited space between the grain or feed truck and the exit door which was 24 inches at the maximum. Another constraint dealt with the height of the exit door, so rather than design the grid stand for the door specifications is was designed for the height of the truck. Given these constraints each grid stand was constructed out of 2X6 inch pine lumber and the three sampling points were situated at 3, 6 and 9 feet as measured from the base of the stand. These stands were designed to be free standing, but given the limited space between the truck and the exit door frame, sand bags were used to anchor each stand when necessary. Each sampling point on the grid stand consisted of a transition to which a 8X10 inch filter cassette could be clamped on one side and a flexible 2 inch vacuum hose to the other. This hose then connected to a portable fan unit that was powered by a gas generator. Each portable fan unit had an on/off power switch, a digital timer and a magnahelic gage to measure pressure drop across a pre-calibrated orifice meter. These timers facilitated the recording of sampling time. During the preliminary testing at Feed Mill A, the grid sampling performed well without any major modifications. However, during the sampling of one grain truck, there was an abundance of "bee's wings" which

[2] This appendix was prepared by Michael A. Demny, Graduate Research Assistant.

contaminated the filter media. After returning to the lab, these filters were weighed with the bee's wings still on the filters, then with tweezers the bee's wings were removed and the filters weighed again. During the analysis of these weights, the weight of the bee's wings was determined to be negligible. However, for accuracy during the actual sampling at Feed Mills B, C and D a screen was constructed and placed approximately 8 inches in front of the three sampling points on each grid stand. The purpose of the screen was to minimize bee's wings contamination of the filter media.

It was hypothesized that the concentration of particulate leaving the grain receiving or feed loading shed would be uniform throughout, and the total mass of particulate collected could be applied to the net exit area and an emission factor derived. At Feed Mill A, it was visually apparent that the dust plume during the grid sampling would result in a higher sampled concentration at the lower sampling points. Moreover, the analysis of the filters exposed during the grid sampling at Feed Mill A confirmed this observation. The net weights indicated that higher loading occurred on the lower sampling points and decreased with height. Realizing that there was not a uniform concentration at the exit of the shed, we decided that the exit area used in calculations required divisions that would correlate to each individual sampling point. This process would allow each of the six sampled concentrations to be related to a specified sampled area, thus producing a more accurate calculation of an emission factor. Below is an example of actual data obtained during the grid sampling at Feed Mill B, note the decrease in the filter loading to its respective sampled area as height increases. **(Figure D-1)**

Figure D-1: Grid Sampling



The calculation of an emission factor for the grid sampling procedure requires the total mass of dust emitted during the unloading or feed loading operation. This calculation involves the determination of the sampled concentration and the volume of sampled air. The total mass of dust emitted was then divided by mass of grain/feed unloaded to determine the emission factor. Equation D-1 is used to find the sampled concentration for each sampled area.

$$C = FL / (Q_s * t) \qquad \text{(D-1)}$$

where

- C = sampled concentration (g/m^3)
- FL = filter loading (grams)
- Q_s = sampling rate (m^3/min), and
- t = sampling time

Equation D-1 was applied to all six sampled areas to obtain independent concentrations. These results are located in **Table D-1** and were determined using data for Truck B01 (**Table B-2**).

Table D-1: Truck B01 Sampled Concentration Results†

Sampler Number	Filter Loading (grams)	Sampling Rate (m^3/min)	Sampling Time (min)	Concentration (g/m^3)
1	0.253	1.25	5.40	0.0376
2	0.189	1.25	5.40	0.0280
3	0.136	1.25	5.40	0.0202
4	0.307	1.25	5.10	0.0483
5	0.373	1.25	5.10	0.0588
6	0.670	1.25	5.10	0.1055

† The numbers denoted in this table have been rounded. Actual data was not rounded until the final result was obtained.

Equation D-2 was used to determine the volume of sampled air for each sampled area.

$$V_s = 0.0283 v_{ws} \bullet A_i \bullet t \quad \text{(D-2)}$$

where,

V_s = volume of sampled air (m^3)
v_{ws} = average air velocity (ft/min)
A_i = area associated to the sampling point (ft^2, i= 1 to 6), and
t = sampling time (min)

Equation D-2 was applied to all six sampled areas to obtain the corresponding volume of sampled air. These results are located in **Table D-2** and were determined using data for Truck B01 (**Tables B-2**).

Table D-2: Truck B01 - Volume of Sampled Air Results†

Sampler (#)	Average Air Velocity (ft/min)	Area (ft^2)	Sampling time (min)	Volume of Sampled Air (m^3)
1	40	25	5.4	152.8
2	40	6	5.4	36.7
3	40	29	5.4	177.3
4	40	29	5.1	167.4
5	40	6	5.1	34.6
6	40	25	5.1	144.3

† The numbers denoted in this table have been rounded. Actual data was not rounded until the final result was obtained.

Equation D-3 was used to determine the mass of dust emitted from each area of the grid sampling system.

$$M_a = C * V_a \qquad \text{(D-3)}$$

where

M_a = mass of dust emitted for the corresponding area (grams)
C = sampled concentration (g/m^3), and
V_a = volume of sampled air (m^3)

The results from equation D-3 were calculated with data from Tables D-1 and D-2 **(Table D-3)**.

Table D-3: Truck B01 - Mass of Dust Emitted†

Sampler (#)	Sampled Concentration (g/m^3)	Volume of Sampled Air (m^3)	Mass of Dust Emitted (grams)
1	0.0376	152.8	5.75
2	0.0280	36.7	1.03
3	0.0202	177.3	3.58
4	0.0483	167.4	8.09
5	0.0588	34.6	2.03
6	0.1055	144.3	15.22
Sum(M_t)			35.7

† The numbers denoted in this table have been rounded. Actual data was not rounded until the final result was obtained.

The emission factor was calculated using equation D-4.

$$EF = 0.0022M_t/W \qquad \text{(D-4)}$$

where

EF = emission factor (lbs/ton)
M_t = total mass of dust emitted (grams)
W = total mass of grain/feed unloaded (tons)

For Truck B01, the total mass of grain unloaded(W) was 28.94 tons **(Table B-2)** and the total mass of dust emitted(M_t) was 35.7 grams **(Table D-3)** yielding an emission factor(EF) of 0.0027 lbs/ton.

APPENDIX E

DESIGN AND TESTING OF PRESEPARATOR CYCLONE[3]

One of our protocols used to measure the emission factors from grain receiving at feed mills was to enclose the bottom of the truck and capture the entrained dust with four sampling systems. This protocol was conceived to provide a more direct measurement of the pounds of dust emitted per ton of grain during the unloading operation. It was assumed that by measuring all of the dust entrained in air directly rather than calculating the mass of dust escaping by measuring the concentration of particulate leaving the shed and multiplying by the volume rate of flow (grid sampling) a more accurate measurement would result. It was anticipated that as much as four pounds of dust would escape during the unloading of 1000 bushels (28 tons) of corn using the interim emission factor published by EPA for corn of 0.15 lbs/ton (0.15 x 28 = 4.2 pounds of dust). We anticipated using four samplers however the filter associated with each high volume sampler (HiVol) had a loading limitation of 2 grams. As the dust loading on the filter increased, the pressure drop across the fan increased. At a filter loading of 2 grams, it was not possible to maintain the desired sampling volume rate of flow. In order to utilize this protocol, we were required to design a preseparator to capture dust and minimize the number of HiVol filter changes while the grain was being unloaded. It was our desire to capture all the dust entrained in the enclosed volume between the bottom of the truck and the pit without having to change filters during the unloading process. This would require that each sampling system would be able to capture one pound of dust (454 grams).

The cyclone preseparator was modeled after the 1D2D cyclone (Simpson, 1996), which is a low pressure cyclone designed for use in the cotton industry to separate trash and fine dust containing a high percentage of lint fiber. We will refer to it as the "barrel" cyclone in this report. After initial laboratory tests, it was concluded that the barrel cyclone was able to obtain efficiencies above 99% for corn dust with a design inlet velocity of 2400 feet per minute (fpm). The dimensions of the barrel cyclone are similar to the 1D2D cyclone. It has a length of 3D and utilizes the 1D2D inlet and outlet design (see **Figure E-1**). The 1D2D cyclone has a barrel (1D) and a cone (2D) while the barrel cyclone has a barrel length of 3D and no cone. The bottom of the barrel cyclone is connected to a dust containment chamber to hold particulate matter captured by the cyclone.

The initial sampling trip was used to test and evaluate the various sampling protocols. One result of this trip was a concern that the outer vortex in the barrel cyclone was continuing through the barrel and into the dust collection chamber. This phenomena

[3] This appendix was prepared by Andrew W. Tullis, Student Assistant, S. Shawnacy Flannigan, Graduate Research Assistant and Michael A. Demny, Graduate Research Assistant.

could result in reentrainment of dust and an increase in emission concentrations especially when capturing as much as 1 pound of particulate in the containment chamber. To correct this problem, a vortex inverter (a small cone 5 inches in diameter with a 45 degree slope) was placed in the dust containment chamber (see **Figure E-2**). The purpose of the vortex inverter was to prevent the possible reentrainment of dust by forcing the outer vortex to turn upward before reaching the dust containment chamber. Different sizes and shapes of inverters were tested at varying positions in the collection chamber. The height of the inverter in the collection chamber had little effect on efficiency but there was a slight decrease in the pressure drop across the cyclone as it was positioned higher. The larger diameter inverters tended to reduce the pressure drop and increase efficiency compared to the smaller inverters. Vortex inverters were tested with slopes of 30, 45 and 60 degrees. A 45 degree slope was chosen. The inverter was placed 7 inches from the base of the dust collection chamber with the tip located at the base of the barrel cyclone. This position was chosen to allow sufficient space for dust to fall between the vortex inverter and the barrel, to maximize the volume of the dust collection chamber, and to maximize efficiency. After the inverter was permanently placed into position, the cyclone was tested and found to have an efficiency of 99.7% on corn dust. A series of 5 tests were conducted in the lab with the barrel cyclone to determine performance characteristics and to insure that the sampling system could capture 1 pound (454 grams) of corn dust without overloading the HiVol filter. For the 1 pound tests, the inlet loading of corn dust to the sampling system was approximately 10 g/m^3 for a period of 45 minutes. It was found that 442.1 grams were captured in the dust collection chamber, 1.4 grams penetrated the cyclone and 6.5 grams were deposited on the inner surface of the cyclone. See **Tables E-1 & E-2**.

Table E-1: Data from One Pound Tests

Total Dust Loaded (g)	Dust Captured (g)	Penetration (g)	Deposition (g)
450	442.1	1.4	6.5

Table E-2: Cyclone Performance from One Pound Tests

Cyclone Efficiency (%)	Deposition (%)	Emission Concentration (mg/m^3)
99.68	1.44	27.5

Deposition Testing

During the operation of the cyclone small amounts of particulate deposited on the inner surface. In order to obtain an accurate measure of particulate material captured, it is important to account for the mass deposited. Tests were performed in the lab to simulate the loading of the cyclone in the field. There were two different sampling procedures used in the field to obtain data, one was "over the truck" sampling and the other was "under the truck" sampling.

"Over the Truck" Sampling for Deposition

Tests were performed using the same "over the truck" sampling procedure and system used at the feed mills. A 10 foot long piece of 1.5 inch diameter galvanized conduit with a 90 degree elbow and an inlet tube was connected to a barrel cyclone. A centrifugal fan was used to pull air through the system. The volumetric flow rate was controlled using a calibrated orifice meter and a variac. The flow rate was maintained at 52 cfm corresponding to the volume rate of flow required to maintain an inlet velocity of 2400 fpm (the design velocity of the barrel cyclone). Each test was run for 2 minutes with 5 grams of corn dust loaded at a constant rate. After 4 repetitions (equivalent to 4 trucks) the filter was changed and post weighed. A total of 16 trucks were simulated requiring 4 filters. This was done to simulate actual sampling conditions and procedures to obtain the average amount of deposition that occurred on the sampling trip. Test results are shown in **Table E-3.**

Table E-3: Results of Deposition Tests for "over the Truck" Sampling

Total dust loaded (g)	Elapsed time (min)	Dust on filter (g)	Dust captured (g)	Total deposition (g)	Deposition per truck (g)	Deposition per truck (%)
20	8	0.1879	18.9754	0.8367	0.2092	1.00
20	8	0.0587	19.9066	0.0347	0.0087	0.04
20	8	0.0632	19.5828	0.3540	0.0885	0.40
20	8	0.6120	20.2074	0 (-0.2074)	0	0
Average		0.0928	19.4883	0.4085	0.1021	0.48
Standard deviation		0.2613	0.4727	0.4038	0.4038	0.4850

"Under the Truck" Sampling for Deposition

The deposition testing system used to simulate "under the truck" sampling utilized the same system as "over the truck" testing except the 10 foot inlet was replaced with a 6 inch inlet tube. The amount of time it took to unload 1 truck, typically ranged from 20 to 30 minutes and in that time the average amount of total particulate captured was 115 grams (approximately 0.25 pounds). To simulate this time and loading, 50 grams of corn dust was loaded in 25 minutes at a constant rate. One filter was used for each test with 4 replications. Test results are shown it **Table E-4**.

Table E-4: Results of Deposition Tests for "Under the Truck" Sampling

Total dust loaded (g)	Elapsed time (min)	Dust on filter (g)	Dust captured (g)	Deposition per truck (g)	Deposition per truck (%)
50	25	0.0938	48.4318	1.4744	3.0
50	25	0.0933	48.8172	1.0895	2.2
50	25	0.0915	49.4309	0.4776	1.0
Average		0.0928	48.8933	1.014	2.1
Standard deviation		0.0010	0.5039	0.5027	1.007

Figure E-1 : Configuration of 1D2D Cyclone

$Bc = Dc / 4$
$Hc = Dc / 2$
$De = Dc / 1.6$
$Lc = Dc$
$Sc = 5 Dc / 8$
$Zc = 2 Dc$
$Jc = Dc / 2$

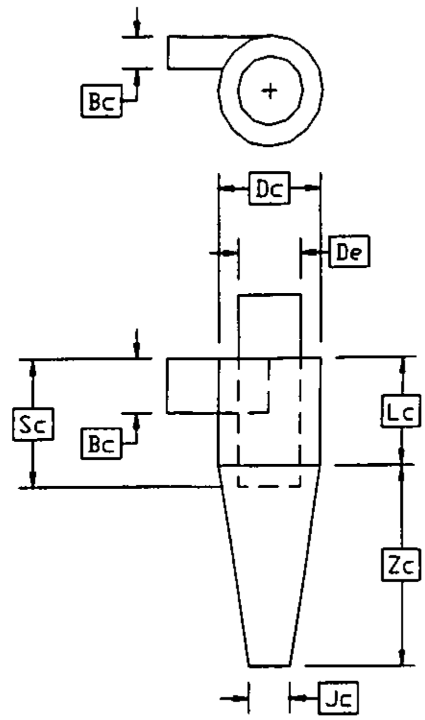
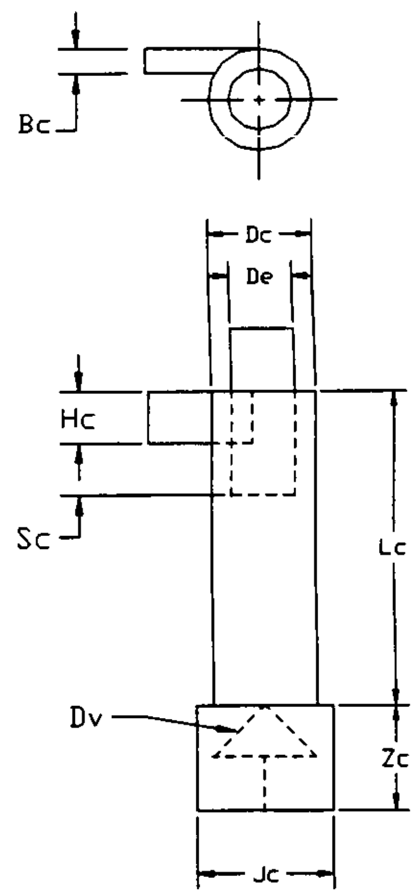


Figure E-2 : Configuration of Barrel Cyclone

$Bc = Dc / 4$
$Hc = Dc / 2$
$De = Dc / 1.6$
$Lc = 3 Dc$
$Sc = 5 Dc / 8$
$Zc = Dc$
$Jc = 1.3 Dc$
$Dv = Dc$



APPENDIX F

Drop Test to Determine Free Fine Dust Content of Grain or Feed[4]

1995d

The Environmental Protection Agency (EPA) published interim AP-42 emission factors for grain unloading and shipping for grain elevators (1995B). It was anticipated that the emission factor for the feed mill grain unloading operation would have a similar value for grain unloading since the two operations are similar. Emission factors for grain handling operations are presently calculated using the equation:

$$EF = A * DR \qquad \text{(Eq. F-1)}$$

where EF = emission factor - pounds of dust entrained in air per ton of grain or feed transferred,
A = emission factor for wheat - pounds of dust entrained in air per ton of wheat, and
DR = dustiness ratio.

The factor DR is defined as a ratio of the dust emission factor of a particular grain to the emission factor of wheat, **Table F-1** lists the EPA (1995) published DR values for various grain types .

TABLE F-1: AP-42 Dustiness Ratio's

Grain	DR
Wheat	1.0
Soybeans	2.5
Corn	2.5
Milo	1.75

Parnell et al (1992) reported fine dust fractions of various grains including corn using an air wash test. An air wash test consists of a one pound sample of grain placed in a box that is covered with a wire mesh sized to allow particulate smaller than100 micrometers to penetrate. Air is pulled through the grain sample, while the box is rotating, and the entrained dust is deposited on a filter. The mass of dust captured on the filter divided by the mass of grain placed in the screen box can be interpreted as a measure of the free fine dust (FFD) content and reported in units of pounds per ton. The results of air wash tests on samples of grain from export elevators (Parnell et al, 1986) are shown in **Table F-2**.

[4] This appendix was prepared by S. Shawnacy Flannigan, Graduate Research Assistant.

TABLE F-2: Free Fine Dust Content Results (Parnell,1986)

Grain	Minimum FFD (lbs/ton)	Maximum FFD (lbs/ton)
Wheat	0.4	0.7
Soybeans	0.5	1.9
Corn	1.3	8.1

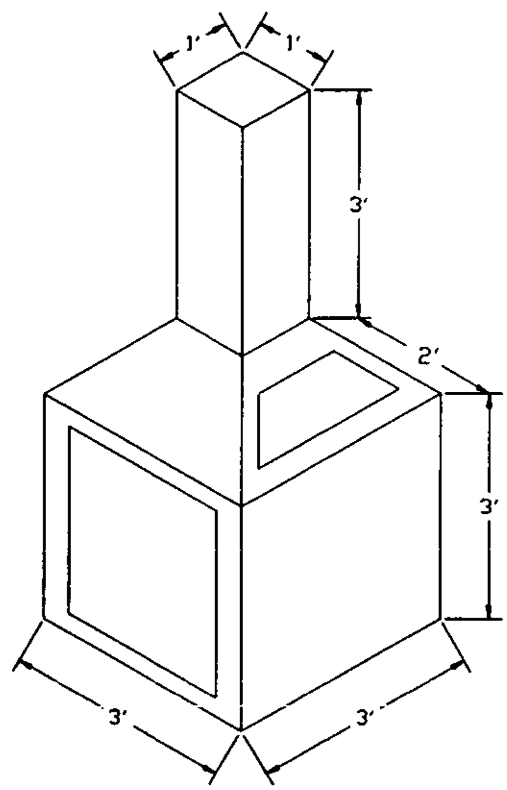
These values are similar to the EPA DR values. However, the air washing process is both time consuming and tedious. OSHA used 0.1% (two pounds per ton) as the free fine dust content of grains (USDA, 1978) when evaluating the grain dust explosion hazard at grain elevators.

One of our study objectives was to determine the FFD content of grain/feed unloaded/loaded during the sampling periods. Typically, an air wash would be performed to determine the FFD. However, because an air wash test is tedious and time consuming, it was an impractical method for determining FFD in the field.

At the International Conference on Air Pollution from Agricultural Operations in Kansas City, Missouri in February 1996, a representative of Midwest Research Institute presented an oral report that included a description of a drop test to determine dust content of grain samples. This new method of determining dust content was quick and simple. The drop test consisted of dropping a known mass of grain into a chamber. During the fall and upon impact dust would be entrained in the air. The entrained particulate could then be captured on a filter. It was hypothesized that this concept would provide an accurate measurement of the dust content in grain

A drop test chamber was designed and constructed. The design consisted of a 3'x3'x3' chamber, a 3'x3'x2' transition, and a 1'x1'x3' stack. The volume of the drop test chamber was calculated to be 39 cubic feet. An inlet was placed on the side of the chamber to allow air to be pulled from the chamber and through a filter (sampling) **(Figure 22)**.

Figure F-1: Drop Test Dimensions



Prior to the sampling trip, tests were performed to determine operating parameters including sampling rate, sampling time, and grain sample size. The following operating parameters were selected based upon initial testing results:

(1) 3 pound grain samples.
(2) sampling rate of 75 cubic feet per minute, and
(3) sampling time of 3 minutes.

These parameters were based on results as well as observations resulting from initial tests. The three pound grain sample was selected because of the physical constraints of the system. These constraints include scaling a ten foot step ladder to drop the sample. The sample weight needed to be light enough to avoid possible injury or accident on the ascent, but also provide an adequate representation of the grain. The sampling rate of 75 cfm was chosen to provide a relatively high air change rate (two per minute) without overloading the fan. The three minute sampling time was selected after performing several tests with various sampling times in the lab on corn samples obtained from feedmill A. The test results are shown in **Table F-3**.

Table F-3: Analysis of Test Results for the Drop Test

Truck #	Time (min)	Initial Weight (gm)	Final Weight (gm)	Difference (gm)	Drop Test FFD (lbs/ton)	Average FFD (lbs/ton)	Standard Deviations (lbs/ton)
5	5	8.0084	8.6774	0.6690	0.9824		
5	5	7.8390	8.6987	0.8597	1.2624	1.1722	0.1645
5	5	7.7793	8.6454	0.8662	1.2720		
5	4	8.4434	9.4371	0.9938	1.4593		
5	4	7.8405	8.9963	1.1557	1.6971	1.6388	0.1585
5	4	8.0779	9.2764	1.1985	1.7599		
5	3	7.9235	8.9606	1.0371	1.5229		
5	3	7.8512	8.9369	1.0857	1.5943	1.6154	0.1047
5	3	7.9381	9.1156	1.1775	1.7291		
5	2	7.8947	8.9401	1.0454	1.5351		
5	2	8.4871	9.4665	0.9794	1.4382	1.4891	0.0487
5	2	8.4660	9.4835	1.0175	1.4941		
Average					**1.4789**		
Standard Deviation					**0.2228**		
6	4	8.5480	9.0162	0.4682	0.6875		
6	4	8.4979	9.0030	0.5051	0.7417	0.7210	0.0293
6	4	8.6128	9.1126	0.4997	0.7338		
6	3	8.6418	9.1561	0.5143	0.7552		
6	3	8.4773	9.0000	0.5227	0.7675	0.7833	0.0385
6	3	8.4375	9.0008	0.5633	0.8272		
Average					**0.7522**		
Standard Deviation					**0.0458**		
7	5	7.9720	8.0952	0.1231	0.1808		
7	5	8.0121	8.1414	0.1293	0.1899	0.1773	0.0145
7	5	7.7485	7.8583	0.1099	0.1614		
7	4	8.3847	8.5842	0.1995	0.2930		
7	4	8.3794	8.5191	0.1397	0.2051	0.2304	0.0545
7	4	8.2968	8.4284	0.1316	0.1932		
7	3	7.7506	7.9396	0.1890	0.2775		
7	3	8.0051	8.1771	0.1719	0.2524	0.2473	0.0330
7	3	7.8772	8.0217	0.1444	0.2120		
7	2	8.5761	8.7961	0.2200	0.3231		
7	2	8.5280	8.7037	0.1756	0.2579	0.2579	0.0652
7	2	8.7105	8.8417	0.1312	0.1927		
Average					**0.2282**		
Standard Deviation					**0.0509**		
8	5	7.9589	8.2200	0.2107	0.3094		
8	5	7.8741	8.1609	0.2868	0.4211	0.3751	0.0584
8	5	7.8901	8.1591	0.2689	0.3949		
8	4	8.3779	8.7387	0.3608	0.5298		
8	4	8.6604	8.9900	0.3296	0.4840	0.4671	0.0726
8	4	8.5371	8.8011	0.2639	0.3875		
8	3	8.4504	8.7854	0.3350	0.4919		
8	3	7.9847	8.3002	0.3155	0.4633	0.5119	0.0611
8	3	7.8177	8.2130	0.3953	0.5805		
Average					**0.4514**		
Standard Deviation					**0.0822**		

It was determined that three and four minute sampling times consistently yielded higher concentrations than either two or five minute sampling times. In addition, all standard deviations were similar. It is unclear why the five minute sampling period consistently produced lower measurements of free fine dust content. Additional tests were performed to determine optimum sampling times. A ten percent mixture of fly ash and clean corn was prepared for the tests. The results of the second series of tests are shown in **Table F-4**.

Table F-4: Drop Test Results Using "Spiked" Grain

Sample Type	Time (min)	Filter #	Initial Weight (gm)	Final Weight (gm)	Difference (gm)	Drop Test FFD (lbs/ton)
Spiked Corn	4	B2-1	7.9144	10.4128	2.4984	3.6687
Spiked Corn	4	B2-2	7.9998	10.3340	2.3341	3.4275
Spiked Corn	4	B2-3	8.0056	9.7647	1.7591	2.5831
Spiked Corn	4	B2-4	7.9315	9.7174	1.7859	2.6225
Spiked Corn	3	B2-5	7.9666	9.2202	1.2537	1.8410
Spiked Corn	3	B2-6	8.1347	10.0796	1.9448	2.8558
Spiked Corn	3	B2-7	7.8637	9.1728	1.3091	1.9223
Spiked Corn	3	B2-8	7.9494	10.2498	2.3004	3.3780

One of our goals was to perform a minimum of four drop tests in the same amount of time as it would take to unload a truck. Typically, hopper bottom trucks unload 1,000 bushels in 15 minutes. We chose to use a three minute sampling period The three minute sampling period was used for all grain/feed samples to ensure that the results are comparable. Four drop tests were performed for each load of grain and feed unloaded or loaded, respectively. The multiple tests were conducted to obtain a more accurate measurement of the free fine dust content of each load.

The measurement of FFD content of feed presented unique problems. Feed is typically loaded into trucks at moisture contents of approximately 20%. As a consequence of the high moisture content (compared to grain), the "free" fine dust in feed is significantly less than that of grain. In order to measure the FFD of feed, the drop tests procedures were modified. Initial tests results suggested that a three pound drop for feed was insufficient. This was concluded after several test failed to produce consistently measurable amounts of dust on the filters. The sample size was increased to a five pound drop. In addition, two drops were performed prior to changing the filter. This change in procedure resulted in a larger mass of dust being deposited on the filter.

There were two objectives for performing the drop test during the sampling trip:

(1) to determine the relationship between drop test results and measured emission factors and

(2) to measure the free fine dust content (FFD) of each load of grain and feed sampled.

If the drop test results were sensitive to changes in grain and feed free fine dust contents, the results of these tests would help explain small variations in measured emission factors.

A regression analysis was performed to determine if a relationship existed between the drop test FFD values and the measured emission factors. The regression analysis results are shown in **Figure F-2** and **Table F-5**.

The regression analyses results suggest that there was no relationship between the drop test measurements of FFD and calculated emission factors. There are several possible reasons for this:

(1) The grain and feed samples may not have accurately reflected the free fine dust present in the load. For example, there were times that we obtained our drop test samples from the top of the truck and it is likely the fine dust migrated to the bottom of the load during transport.

(2) The capture velocity at the inlet of the sampling system exceeded 6,000 fpm which likely resulted in capturing large particles.

At this point, we feel that the drop test needs further investigation, and perhaps modifications to the design. Due to the simplicity of this method of measuring fine dust content in grain, we feel further development is warranted.

<u>**Figure F-2: Comparison of Emission Factors and Drop Test Results**</u>

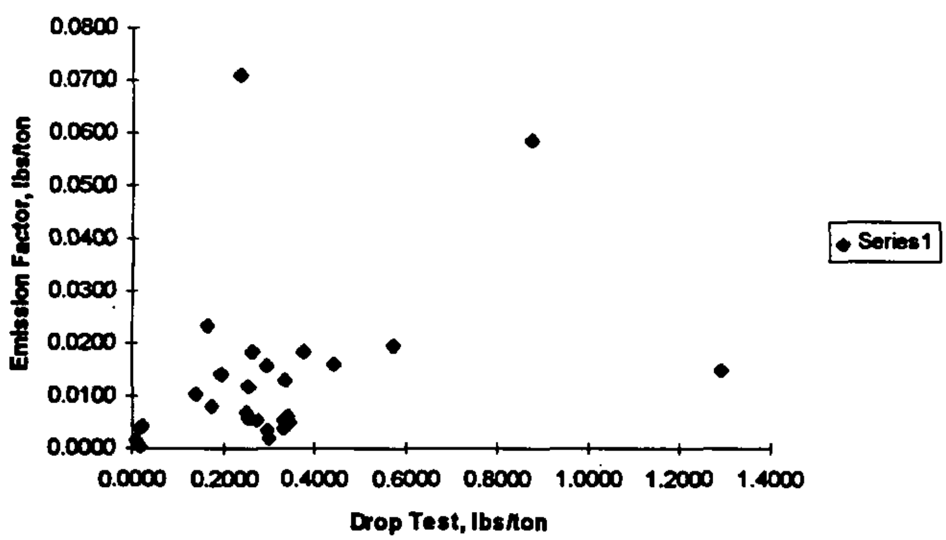


Table F-5: Regression Analysis

Regression Statistics	
Multiple R	0.341621
R Square	0.116705
Adjusted R Square	0.081373
Standard Error	0.015531
Observations	27

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000797	0.000797	3.303101	0.081155
Residual	25	0.006031	0.000241		
Total	26	0.006827			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.007127	0.004665	1.527668	0.139149	-0.002481	0.01673	-0.00248	0.01673
X Variable 1	0.020892	0.011495	1.817444	0.081155	-0.002783	0.04456	-0.00278	0.04456

Table F-6: Comparison of Emission Factors and Drop Test Results

Truck #	Drop Test lbs/ton	Emission Factor lbs/ton
B-03	0.4430	0.0163
B-04	0.3398	0.0060
B-05	0.2550	0.0120
B-06	0.3449	0.0049
B-07	0.3373	0.0129
B-30	0.1635	0.0235
C-01	0.3298	0.0054
C-02	0.3006	0.0018
C-03	1.2921	0.0149
C-04	0.2739	0.0053
C-05	0.2972	0.0033
C-06	0.2364	0.0711
C-07	0.1982	0.0144
C-08	0.1725	0.0081
C-09	0.1400	0.0104
C-10	0.8772	0.0590
C-11	0.2565	0.0058
C-12 to 15	0.0171	0.0003
C-16 to 20	0.0090	0.0015
C-21 to 24	0.0222	0.0043
C-28 to 30	0.0201	0.0038
D-01	0.2932	0.0156
D-03	0.5743	0.0196
D-04	0.3313	0.0038
D-05	0.2496	0.0071
D-06	0.3743	0.0186
D-07	0.2642	0.0185

Table F-7: Drop Test Results

Truck #	Grain/Feed Type	Filter #	Dust on filter gm	Grain/Feed dropped(lbs)	FFD (TSP) lbs/ton	PM-10 %	FFD (PM-10) lbs/ton
B-02	corn	172	0.4044	3	0.5938	38.10	0.2262
B-02	corn	171	0.3508	3	0.5151		
B-02	corn	170	0.3058	3	0.4490		
B-02	corn	169	0.1507	3	0.2213		
Average					0.4448		
B-03	corn	161	0.2763	3	0.4057		
B-03	corn	160	0.3118	3	0.4579		
B-03	corn	159	0.3253	3	0.4776	20.82	0.0994
B-03	corn	158	0.2934	3	0.4309		
Average					0.4430		
B-04	corn	229	0.2766	3	0.4061	21.31	0.0865
B-04	corn	228	0.1470	3	0.2158		
B-04	corn	227	0.2496	3	0.3666		
B-04	corn	231	0.2525	3	0.3708		
Average					0.3398		
B-05	corn	241	0.1696	3	0.2490		
B-05	corn	221	0.1727	3	0.2536		
B-05	corn	219	0.1927	3	0.2830	18.39	0.0520
B-05	corn	220	0.1598	3	0.2346		
Average					0.2550		
B-06	corn	245	0.2097	3	0.3079		
B-06	corn	247	0.2636	3	0.3871	24.29	0.0940
B-06	corn	246	0.2137	3	0.3138		
B-06	corn	230	0.2525	3	0.3708		
Average					0.3449		
B-07	corn	222	0.2063	3	0.3029		
B-07	corn	244	0.2421	3	0.3555		
B-07	corn	243	0.2126	3	0.3122		
B-07	corn	242	0.2578	3	0.3786	23.85	0.0903
Average					0.3373		
	mixed feed	257	0.0484	5	0.0427		
	mixed feed	256	0.0508	5	0.0447		
	mixed feed	265	0.0644	5	0.0567	11.31	0.0064
	mixed feed	255	0.0532	5	0.0469		
Average					0.0477		

Table F-7: Drop Test Results (Cont.)

Truck #	Grain/Feed Type	Filter #	Dust on filter gm	Grain/Feed dropped (lbs)	FFD (TSP) lbs/ton	PM-10 %	FFD (PM-10) lbs/ton
	corn flakes	266	0.1166	5	0.1027	20.36	0.0209
	corn flakes	268	0.0559	5	0.0492		
	corn flakes	269	0.0702	5	0.0618		
	corn flakes	267	0.0374	5	0.0330		
Average					0.0617		
B-30	corn	299	0.1027	3	0.1508		
B-30	corn	290	0.1259	3	0.1849	23.98	0.0443
B-30	corn	301	0.1159	3	0.1701		
B-30	corn	303	0.1010	3	0.1484		
Average					0.1635		
C-01	corn	324	0.2102	3	0.3087		
C-01	corn	323	0.2292	3	0.3365	24.35	0.0819
C-01	corn	322	0.2263	3	0.3323		
C-01	corn	321	0.2328	3	0.3418		
Average					0.3298		
C-02	wheat mids	316	0.2861	3	0.4201	22.02	0.0925
C-02	wheat mids	315	0.1504	3	0.2209		
C-02	wheat mids	314	0.1728	3	0.2537		
C-02	wheat mids	311	0.2096	3	0.3077		
Average					0.3006		
C-03	corn	302	1.0079	3	1.4800	29.42	0.4354
C-03	corn	300	0.7966	3	1.1698		
C-03	corn	288	0.8956	3	1.3151		
C-03	corn	252	0.8195	3	1.2034		
Average					1.2921		
C-04	corn	348	0.1784	3	0.2619		
C-04	corn	347	0.1688	3	0.2478		
C-04	corn	350	0.1995	3	0.2930	24.38	0.0714
C-04	corn	349	0.1995	3	0.2929		
Average					0.2739		
C-05	corn	353	0.1953	3	0.2867		
C-05	corn	351	0.2284	3	0.3353	21.91	0.0735
C-05	corn	355	0.1940	3	0.2849		
C-05	corn	354	0.1920	3	0.2819		
Average					0.2972		

Table F-7: Drop Test Results (Cont.)

Truck #	Grain/Feed Type	Filter #	Dust on filter gm	Grain/Feed dropped (lbs)	FFD (TSP) lbs/ton	PM-10 %	FFD (PM-10) lbs/ton
C-06	com	357	0.1834	3	0.2693	23.07	0.0621
C-06	com	356	0.1425	3	0.2092		
C-06	com	358	0.1728	3	0.2537		
C-06	com	253	0.1452	3	0.2132		
Average					0.2364		
C-07	com	370	0.1480	3	0.2174	19.10	0.0415
C-07	com	379	0.1310	3	0.1924		
C-07	com	372	0.1144	3	0.1679		
C-07	com	371	0.1464	3	0.2150		
Average					0.1982		
C-08	com	369	0.1287	3	0.1890		
C-08	com	368	0.0970	3	0.1425		
C-08	com	361	0.0954	3	0.1402		
C-08	com	359	0.1486	3	0.2182	17.14	0.0374
Average					0.1725		
C-09	com	387	0.1042	3	0.1531	23.54	0.0360
C-09	com	388	0.0856	3	0.1257		
C-09	com	389	0.0904	3	0.1327		
C-09	com	390	0.1013	3	0.1487		
Average					0.1400		
C-10	com	409	0.6148	3	0.9027		
C-10	com	411	0.5288	3	0.7765		
C-10	com	412	0.7049	3	1.0350	26.83	0.2777
C-10	com	413	0.5411	3	0.7946		
Average					0.8772		
C-11	com	397	0.1792	3	0.2631		
C-11	com	398	0.1838	3	0.2700	38.15	0.1030
C-11	com	399	0.1628	3	0.2391		
C-11	com	400	0.1730	3	0.2540		
Average					0.2565		
C-12	ration# 5	436	0.0693	10	0.0305	28.37	0.0087
C-12	ration# 5	435	0.0237	10	0.0104		
C-12	ration# 5	434	0.0233	10	0.0102		
Average					0.0171		
C-16	raion# 5	433	0.0328	10	0.0145	21.02	0.0030
C-16	raion# 5	410	0.0237	10	0.0104		
C-16	raion# 5	438	0.0048	10	0.0021		
Average					0.0090		

Table F-7: Drop Test Results (Cont.)

Truck #	Grain/Feed Type	Filter #	Dust on filter gm	Grain/Feed dropped (lbs)	FFD (TSP) lbs/ton	PM-10 %	FFD (PM-10) lbs/ton
C-21	ration# 6	459	0.0649	10	0.0286	22.16	0.0063
C-21	ration# 6	437	0.0408	10	0.0180		
C-21	ration# 6	440	0.0455	10	0.0201		
Average					0.0222		
D-07	corn	533	0.1788	3	0.2626		
D-07	corn	535	0.1746	3	0.2564		
D-07	corn	534	0.1750	3	0.2570		
D-07	corn	528	0.1912	3	0.2808	20.05	0.0563
Average					0.2642		
C-28	ration# 6	439	0.0590	10	0.0260	18.40	0.0048
C-28	ration# 6	442	0.0449	10	0.0198		
C-28	ration# 6	441	0.0329	10	0.0145		
Average					0.0201		
D-01	milo	465	0.2158	3	0.3169		
D-01	milo	468	0.1879	3	0.2759		
D-01	milo	467	0.2268	3	0.3331	23.77	0.0792
D-01	milo	463	0.1681	3	0.2468		
Average					0.2932		
D-03	corn	462	0.4001	3	0.5874	22.70	0.1333
D-03	corn	480	0.3784	3	0.5557		
D-03	corn	466	0.3930	3	0.5771		
D-03	corn	481	0.3928	3	0.5768		
Average					0.5743		
D-04	milo	484	0.2861	3	0.4201	22.46	0.0944
D-04	milo	464	0.2327	3	0.3417		
D-04	milo	483	0.1898	3	0.2787		
D-04	milo	486	0.1939	3	0.2847		
Average					0.3313		
D-05	milo	482	0.1941	3	0.2851	24.03	0.0685
D-05	milo	485	0.1846	3	0.2710		
D-05	milo	488	0.1474	3	0.2165		
D-05	milo	487	0.1538	3	0.2258		
Average					0.2496		
D-06	corn	521	0.2570	3	0.3774		
D-06	corn	520	0.2740	3	0.4023	19.23	0.0774
D-06	corn	527	0.2640	3	0.3877		
D-06	corn	526	0.2247	3	0.3300		
Average					0.3743		

Table F-7: Drop Test Results (Cont.)

Truck #	Grain/Feed Type	Filter #	Dust on filter gm	Grain/Feed dropped (lbs)	FFD (TSP) lbs/ton	PM-10 %	FFD (PM-10) lbs/ton
	corn pellets	532	0.2578	3	0.3786		
	corn pellets	531	0.2630	3	0.3862	14.93	0.0577
	corn pellets	530	0.1877	3	0.2756		
	corn pellets	529	0.1869	3	0.2745		
Average					0.3287		
D-16	ration# 4	559	0.2201	10	0.0970	23.48	0.0228
D-16	ration# 4	557	0.1809	10	0.0797		
D-16	ration# 4	561	0.1551	10	0.0683		
Average					0.0817		
	cotton gin trash	553	1.4637	3	2.1494	32.49	0.6983
	cotton gin trash	555	0.8699	3	1.2774		
	cotton gin trash	552	1.0291	3	1.5112		
	cotton gin trash	554	1.0905	3	1.6013		
Average					1.6348		

APPENDIX G

WEATHER STATION DATA

A weather station was set up at each mill during sampling at the grain unloading and feed loading sheds to collect weather data. Wind velocity and direction data from the weather station was used to calculate the average wind velocity through the sheds. Temperature, vapor pressure and barometric pressure data were used to calculate the actual air density which were used to calculate the flowrates for the samplers that were calibrated for standard temperature and pressure.

The weather data sheets attached are for the grid sampling time periods.

Table G-1: Weather Station Data Feed Mill B
6-10-96/8:55 to 12:45

Date		Time	Temp	RH	Vapor Pr.	Wind Vel.	Wind Dir.	BP	Density
month	day		deg F	%	kPa	mph	deg	in Hg	lbs/ft3
6	10	855	71.00	52.11	1.369	1.337	147	25.65	0.0638
6	10	905	72.30	52.31	1.390	1.472	162	25.65	0.0637
6	10	915	74.50	43.40	1.406	1.215	70	25.66	0.0634
6	10	925	76.10	42.38	1.317	1.125	350	25.66	0.0633
6	10	935	77.40	34.69	1.201	2.336	115	25.65	0.0631
6	10	945	77.70	35.70	1.162	3.080	140	25.65	0.0631
6	10	955	78.00	38.67	1.215	3.845	142	25.65	0.0630
6	10	1005	78.60	37.32	1.249	2.632	152	25.65	0.0630
6	10	1015	79.80	35.43	1.257	2.121	152	25.65	0.0628
6	10	1025	80.30	34.55	1.246	2.622	243	25.65	0.0628
6	10	1035	80.60	35.96	1.205	3.227	280	25.65	0.0627
6	10	1045	80.90	31.98	1.210	2.665	299	25.65	0.0627
6	10	1055	81.70	31.84	1.213	1.677	9	25.65	0.0626
6	10	1105	82.00	30.43	1.219	2.700	337	25.65	0.0626
6	10	1115	82.10	31.23	1.163	2.874	33	25.65	0.0626
6	10	1125	83.00	30.69	1.199	2.210	80	25.65	0.0625
6	10	1135	83.50	29.61	1.178	4.852	154	25.65	0.0624
6	10	1145	82.90	30.15	1.168	4.756	112	25.65	0.0625
6	10	1155	83.70	28.59	1.191	1.832	159	25.65	0.0624
6	10	1205	84.20	30.08	1.183	3.034	124	25.65	0.0623
6	10	1215	84.50	29.94	1.234	2.733	26	25.65	0.0623
6	10	1225	84.40	31.96	1.242	3.875	35	25.65	0.0623
6	10	1235	84.10	29.87	1.219	3.903	27	25.65	0.0623
6	10	1245	85.00	29.33	1.228	3.785	289	25.64	0.0622
Averages:			80.35	34.93	1.236	2.746	152	25.65	0.0628
Std. Dev.			3.93	6.67	0.068	1.048	101	0.00	0.0004

Table G-1: Weather Station Data Feed Mill B (Cont.)

6-11-96/11:30 to 12:00

	Date	Time	Temp	RH	Vapor Pr.	Wind Vel.	Wind Dir.	BP	Density
month	day		deg F	%	kPa	mph	deg	in Hg	lbs/ft3
6	11	10	81.20	28.20	1.079	5.088	104	25.61	0.0626
6	11	1135	81.60	29.68	1.067	4.709	104	25.61	0.0626
6	11	1145	81.90	26.85	1.051	6.519	113	25.61	0.0625
6	11	1155	82.40	28.80	1.040	6.218	133	25.61	0.0625
6	11	1205	82.50	25.83	1.010	6.588	131	25.61	0.0625
Averages:			81.92	27.87	1.049	5.824	117	25.61	0.0625
Std. Dev.			0.54	1.54	0.027	0.867	14	0.00	0.0001

Table G-2: Weather Station Data Feed Mill C

6-13-96/13:35 to 16:05)

	Date	Time	Temp	RH	Vapor Pr.	Wind Vel.	Wind Dir.	BP	Density
month	day		deg F	%	kPa	mph	deg	in Hg	lbs/ft3
6	13	1335	83.60	37.01	1.492	6.072	147	26.84	0.0652
6	13	1345	83.90	36.41	1.467	7.520	142	26.83	0.0652
6	13	1355	84.80	32.56	1.430	6.809	121	26.83	0.0651
6	13	1405	85.20	33.10	1.358	6.067	117	26.83	0.0651
6	13	1415	85.50	31.62	1.361	7.290	146	26.83	0.0650
6	13	1425	86.00	29.39	1.276	3.482	135	26.83	0.0650
6	13	1435	87.20	29.59	1.278	4.617	135	26.82	0.0648
6	13	1445	87.40	28.78	1.302	6.036	158	26.81	0.0648
6	13	1455	87.10	29.32	1.293	8.080	155	26.81	0.0648
6	13	1505	87.50	28.78	1.330	9.920	146	26.81	0.0647
6	13	1515	88.10	28.85	1.316	11.370	122	26.80	0.0647
6	13	1525	88.70	28.24	1.318	8.730	131	26.80	0.0646
6	13	1535	88.50	27.43	1.302	12.270	147	26.79	0.0646
6	13	1545	88.60	28.58	1.308	9.130	121	26.79	0.0646
6	13	1555	88.20	27.97	1.288	12.170	124	26.79	0.0646
6	13	1605	88.40	27.63	1.280	12.050	141	26.78	0.0646
Averages:			86.79	30.33	1.337	8.226	137	26.81	0.0648
Std. Dev.			1.72	2.99	0.068	2.749	13	0.02	0.0002

Table G-2: Weather Station Data Feed Mill C (Cont.)

6-14-96/9:25 to 14:55

Date		Time	Temp	RH	Vapor Pr.	Wind Vel.	Wind Dir.	BP	Density
month	day		deg F	%	kPa	mph	deg	in Hg	lbs/ft3
6	14	925	74.70	56.82	1.664	5.055	3	26.83	0.0663
6	14	935	75.00	56.01	1.680	6.545	1	26.83	0.0662
6	14	945	75.40	56.49	1.690	5.522	11	26.83	0.0662
6	14	955	76.60	52.71	1.679	2.271	172	26.83	0.0660
6	14	1005	77.10	51.70	1.676	2.344	124	26.84	0.0660
6	14	1015	77.50	51.02	1.675	2.388	159	26.84	0.0659
6	14	1025	77.90	50.75	1.671	3.589	21	26.84	0.0659
6	14	1035	78.50	49.60	1.658	2.836	116	26.84	0.0658
6	14	1045	80.50	46.02	1.670	1.629	176	26.84	0.0656
6	14	1055	80.70	46.69	1.654	2.819	128	26.83	0.0655
6	14	1105	79.80	47.29	1.628	3.516	116	26.83	0.0656
6	14	1115	80.30	43.92	1.632	2.983	134	26.83	0.0656
6	14	1125	81.70	43.65	1.638	2.640	139	26.83	0.0654
6	14	1135	81.00	46.14	1.625	4.216	131	26.83	0.0655
6	14	1145	81.90	44.92	1.673	3.132	122	26.83	0.0654
6	14	1155	82.10	46.07	1.678	3.997	128	26.82	0.0653
6	14	1205	82.10	45.39	1.714	3.463	128	26.82	0.0653
6	14	1215	82.90	44.04	1.682	7.030	129	26.82	0.0652
6	14	1225	81.90	46.06	1.688	4.706	117	26.82	0.0654
6	14	1235	82.00	46.12	1.727	6.512	133	26.82	0.0653
6	14	1245	81.70	47.27	1.721	6.671	116	26.82	0.0654
6	14	1255	81.70	47.74	1.750	5.301	113	26.82	0.0654
6	14	1305	81.80	47.47	1.766	6.050	120	26.82	0.0654
6	14	1315	81.50	47.34	1.738	6.479	115	26.81	0.0654
6	14	1325	81.20	47.07	1.748	8.090	121	26.81	0.0654
6	14	1335	81.10	48.82	1.740	7.720	124	26.81	0.0654
6	14	1345	81.20	49.36	1.774	7.360	120	26.81	0.0654
6	14	1355	81.30	50.04	1.804	5.325	114	26.80	0.0654
6	14	1405	81.30	48.96	1.817	6.215	119	26.80	0.0654
6	14	1415	81.50	49.37	1.791	5.286	116	26.80	0.0653
6	14	1425	81.60	49.16	1.806	7.620	118	26.80	0.0653
6	14	1435	82.30	48.49	1.847	5.867	115	26.80	0.0652
6	14	1445	82.70	49.10	1.866	6.316	119	26.79	0.0652
6	14	1455	83.60	42.29	1.849	7.940	124	26.78	0.0650
Averages:			80.41	48.35	1.718	4.983	113	26.82	0.0655
Std. Dev.			2.36	3.48	0.068	1.914	41	0.02	0.0003

Table G-3: Weather Station Data Feed Mill D

6-18-96/6:45 to 11:05

	Date	Time	Temp	RH	Vapor Pr.	Wind Vel.	Wind Dir.	BP	Density
month	day		deg F	%	kPa	mph	deg	in Hg	lbs/ft3
6	18	645	62.08	85.00	1.641	2.834	121	25.89	0.0655
6	18	655	63.18	84.30	1.678	2.363	197	25.89	0.0653
6	18	705	62.84	85.40	1.656	1.346	202	25.89	0.0654
6	18	715	62.91	84.60	1.665	2.620	262	25.89	0.0653
6	18	725	63.70	82.90	1.680	2.478	292	25.89	0.0652
6	18	735	64.66	81.80	1.712	2.874	286	25.89	0.0651
6	18	745	66.27	79.10	1.766	5.614	271	25.89	0.0649
6	18	755	67.55	77.30	1.806	7.280	255	25.89	0.0647
6	18	805	69.17	74.60	1.827	8.140	232	25.89	0.0645
6	18	815	69.99	73.50	1.851	8.040	220	25.89	0.0644
6	18	825	71.10	70.10	1.848	9.510	218	25.89	0.0643
6	18	835	72.20	66.37	1.850	10.580	223	25.89	0.0642
6	18	845	73.40	64.81	1.847	11.670	228	25.89	0.0640
6	18	855	74.70	61.44	1.832	12.780	232	25.89	0.0639
6	18	905	75.50	60.15	1.823	12.820	231	25.89	0.0638
6	18	915	76.40	57.51	1.807	12.710	230	25.89	0.0637
6	18	925	77.40	55.68	1.784	12.330	227	25.89	0.0636
6	18	935	78.30	52.71	1.806	11.630	211	25.89	0.0635
6	18	945	79.20	50.62	1.778	11.590	207	25.90	0.0634
6	18	955	80.00	48.52	1.723	13.170	205	25.89	0.0633
6	18	1005	81.40	45.21	1.688	13.260	210	25.89	0.0631
6	18	1015	82.70	42.37	1.623	15.210	217	25.89	0.0630
6	18	1025	83.50	38.05	1.573	16.120	223	25.89	0.0629
6	18	1035	84.70	36.09	1.530	16.770	325	25.88	0.0628
6	18	1045	85.60	34.68	1.514	17.610	213	25.88	0.0627
6	18	1055	86.70	32.31	1.438	19.380	211	25.88	0.0626
6	18	1105	87.90	30.62	1.418	17.970	208	25.87	0.0624
Averages:			74.19	61.32	1.710	10.322	228	25.89	0.0640
Std. Dev.			8.27	18.39	0.128	5.389	37	0.01	0.0010

APPENDIX H

BACKGROUND SAMPLING

Background samplers were set up at the sampling sites to measure the background concentrations of particulate matter. A PM-10 and a TSP sampler was placed approximately 20 meters away from the grain unloading and feed loading sheds on the upwind side. Whenever there was enough space just outside the sheds the samplers were placed there to give more accurate measurements of background concentrations of particulate matter entering the sheds. On one occasion while sampling at the feed loading shed the samplers were placed just inside the shed on the upwind side. Due to constant variations in wind direction a PM-10 and a TSP sampler were placed on both the upwind side and the downwind side of the sheds. The location of the background samplers for each feed mill are indicated on the data sheets attached.

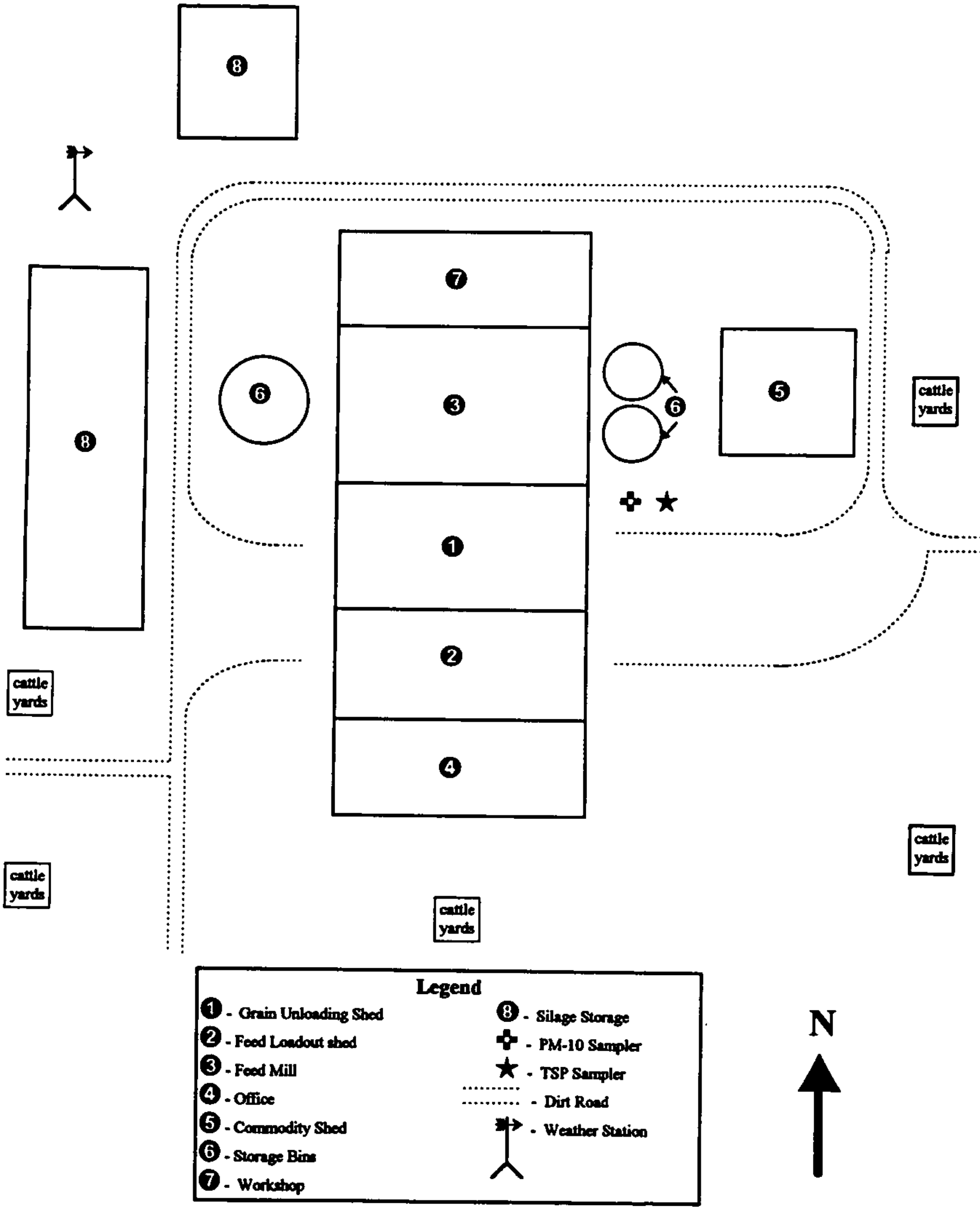
Feed Mill B

The PM-10 and TSP samplers were placed just outside the grain unloading and feed loading sheds on the upwind side. The grid setup was used to measure the background concentrations inside the grain unloading shed without any truck present. The setup is shown in the layout diagram for Feed Mill B (**Figure H-1**).

Table H-1: Background Sampling at Feed Mill B

Date	Time-in	Time-out	Sampler #	Filter #	Dust on filter mg	Sampling time (min)	Sampling rate (cfm)	Concentration (ug/m^3)
6/10/96	8:50	10:10	PM-10	157	32.4200	80	44	325.21
6/10/96	8:50	10:10	TSP	156	Error	80	Error	Error
6/10/96	10:19	14:10	PM-10	185	55.9567	231	44	194.40
6/10/96	10:19	14:10	TSP	183	89.1167	231	52	261.96
6/10/96	14:15	15:30	PM-10	194	86.0133	75	44	920.34
6/10/96	14:15	15:30	TSP	249	370.2967	75	52	3352.61
6/11/96	6:50	10:40	PM-10	263	78.1833	230	44	272.79
6/11/96	6:50	10:40	TSP	264	372.8667	230	52	1100.83
6/11/96	10:45	11:50	PM-10	284	35.1700	65	44	434.21
6/11/96	10:45	11:50	TSP	285	47.9900	65	52	501.34
6/11/96	10:30	11:27	Grid 1	248	60.4000	57	44	850.37
6/11/96	10:30	11:27	Grid 2	254	43.4233	57	44	611.35
6/11/96	10:30	11:27	Grid 3	250	Error	57	44	Error
6/11/96	10:30	11:27	Grid 4	262	46.7767	57	44	658.57
6/11/96	10:30	11:27	Grid 5	261	45.3833	57	44	638.95
6/11/96	10:30	11:27	Grid 6	260	50.0267	57	44	704.32

Figure H-1: General Layout Diagram
Mill B



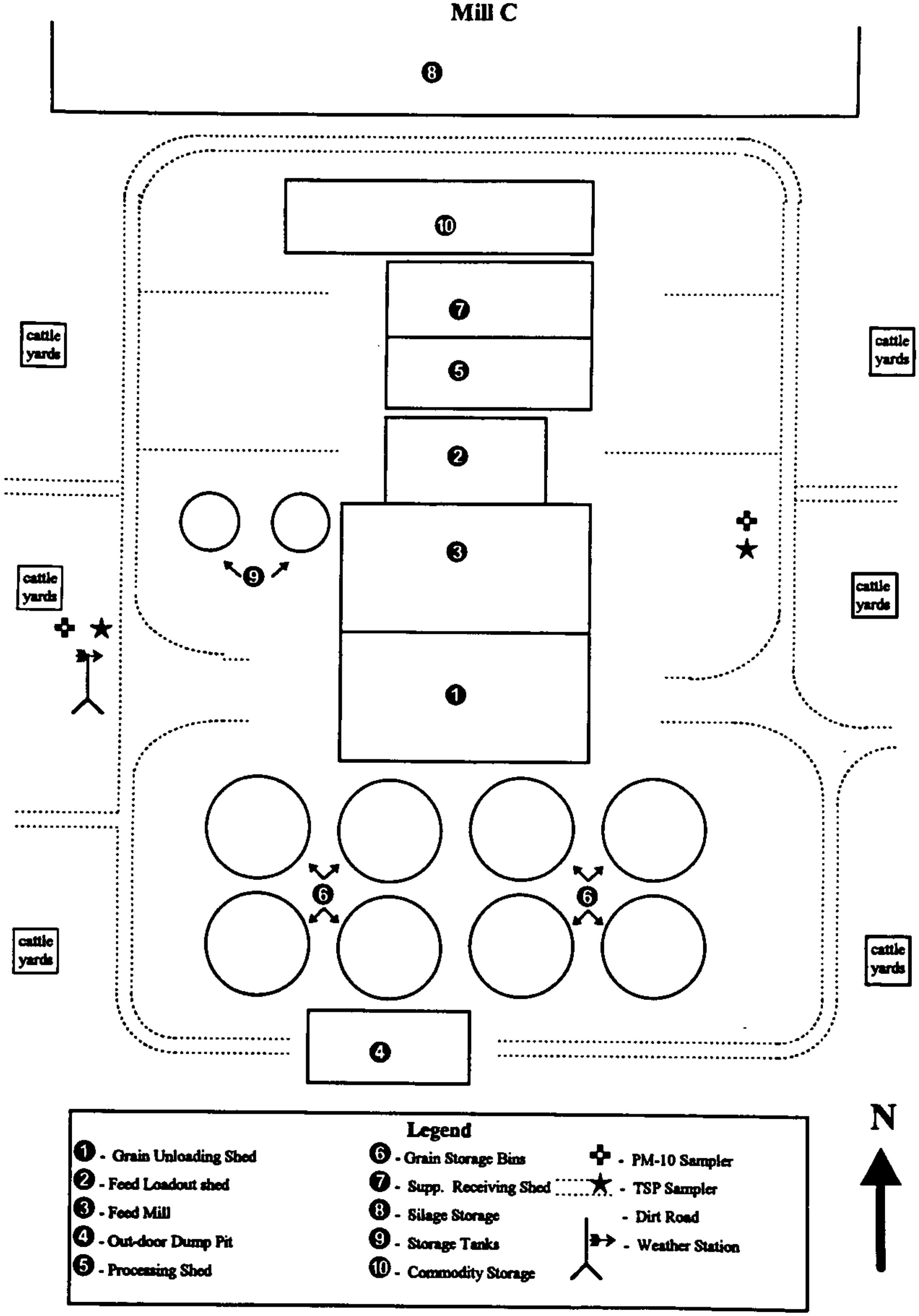
Feed Mill C

A set of PM-10 and TSP samplers were placed on the East (e) and West (w) ends of the grain unloading and feed loading sheds, on the upwind side, to measure the background concentrations of particulate matter, due to constant variations in wind direction. The setup is shown in the layout diagram for Feed Mill C (**Figure H-2**).

Table H-2: Background Sampling at Feed Mill C

Date	Time-in	Time-out	Sampler #	Filter #	Dust on filter mg	Sampling time (min)	Sampling rate (cfm)	Concentration (ug/m^3)
6/13/96	7:25	9:50	PM-10(w)	334	34.1067	145	43	193.15
6/13/96	7:25	9:50	TSP(w)	335	95.5433	145	51	456.20
6/13/96	6:50	9:45	PM-10(e)	318	58.8567	175	43	276.18
6/13/96	6:50	9:45	TSP(e)	317	184.4200	175	51	729.62
6/13/96	9:50	13:05	PM-10(w)	360	97.2067	195	43	409.35
6/13/96	9:50	13:05	TSP(w)	320	95.5433	195	51	339.23
6/13/96	10:00	13:20	PM-10(e)	292	36.8367	200	43	151.24
6/13/96	10:00	13:20	TSP(e)	289	49.2100	200	51	170.35
6/13/96	13:10	17:15	PM-10(w)	319	50.9300	245	43	170.70
6/13/96	13:10	17:15	TSP(w)	345	285.0000	245	51	805.39
6/13/96	13:15	17:21	PM-10(e)	291	46.7300	246	43	155.99
6/13/96	13:15	17:21	TSP(e)	346	146.7367	246	51	412.98
6/14/96	8:20	12:10	PM-10(w)	447	39.9233	230	43	142.54
6/14/96	8:20	12:10	TSP(w)	445	162.2467	230	51	488.40
6/14/96	8:25	12:15	PM-10(e)	448	29.9400	230	43	106.89
6/14/96	8:25	12:15	TSP(e)	444	149.9733	230	51	451.45
6/14/96	12:25	14:45	PM-10(w)	406	27.9300	140	43	163.82
6/14/96	12:25	14:45	TSP(w)	421	118.8900	140	51	587.96
6/14/96	12:30	14:50	PM-10(e)	408	32.0167	140	43	187.79
6/14/96	12:30	14:50	TSP(e)	420	111.2400	140	51	550.12

Figure H-2: General Layout Diagram
Mill C



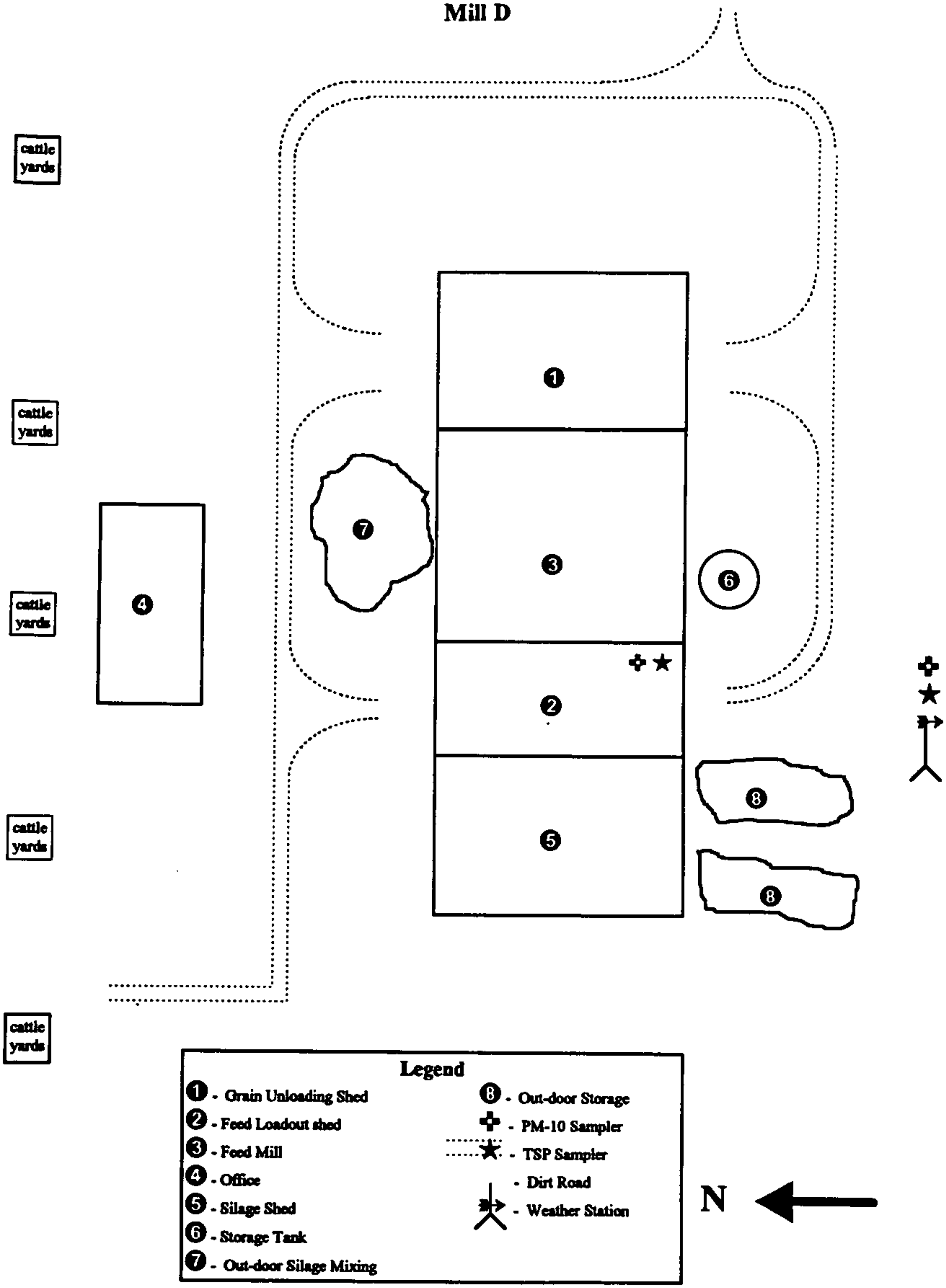
Feed Mill D

For sampling at the grain unloading shed a set of PM-10 and TSP samplers was placed just outside the grain unloading shed (2), on the upwind side, in addition to the one set up near the weather station (1), to give an accurate measure of background concentrations of particulate matter entering the shed. Similarly, a set of PM-10 and TSP samplers was placed just inside the shed (3), on the upwind side, while sampling at the feed loadout shed. The setup is shown in the general layout diagram for Feed Mill D (**Figure H-3**).

<u>Table H-3: Background Sampling at Feed Mill D</u>

Date	Time-in	Time-out	Sampler #	Filter #	Dust on filter mg	Sampling time (min)	Sampling rate (cfm)	Concentration (ug/m^3)
6/17/96	8:30	12:05	PM-10(1)	475	11.3033	215	43	43.17
6/17/96	8:30	12:05	TSP(1)	469	22.7900	215	51	73.39
6/17/96	8:40	11:50	PM-10(2)	496	30.3053	190	43	130.98
6/17/96	8:40	11:50	TSP(2)	471	214.2700	190	51	780.79
6/17/96	12:10	15:07	PM-10(1)	472	10.7500	177	43	49.87
6/17/96	12:10	15:07	TSP(1)	523	11.1600	177	51	43.65
6/17/96	11:55	15:05	PM-10(2)	474	22.7700	190	43	98.41
6/17/96	11:55	15:05	TSP(2)	524	23.5967	190	51	85.99
6/18/96	6:40	9:50	PM-10(1)	543	15.7133	190	43	67.91
6/18/96	6:40	9:50	TSP(1)	497	55.1333	190	51	200.90
6/18/96	9:55	11:00	PM-10(1)	595	4.1500	65	43	52.43
6/18/96	9:55	11:00	TSP(1)	565	5.3600	65	51	57.09
6/18/96	6:45	7:18	PM-10(3)	566	4.5700	33	43	113.72
6/18/96	6:45	7:18	TSP(3)	549	61.2400	33	51	1284.84
6/18/96	7:25	8:26	PM-10(3)	567	11.5267	61	43	155.17
6/18/96	7:25	8:26	TSP(3)	548	65.1167	61	51	739.08
6/18/96	8:35	9:04	PM-10(3)	569	6.9967	29	43	198.12
6/18/96	8:35	9:04	TSP(3)	573	60.2267	29	51	1437.87
6/18/96	9:50	10:46	PM-10(3)	582	19.1167	56	43	280.32
6/18/96	9:50	10:46	TSP(3)	580	79.9200	56	51	988.09

Figure H-3: General Layout Diagram
Mill D



APPENDIX I

HOT-WIRE ANEMOMETER READINGS[5]

The emission factors using the grid sampling protocol were calculated using the volumetric flow rate of air through the shed. This volumetric flow rate was calculated using the average wind speed through the shed during the sampling period. The original plan was to measure these velocities using a hot-wire anemometer. These values found to be highly variable. Therefore, velocity vectors from the weather station data, as discussed in Appendix A, were used to determine the average air velocity through the shed when utilizing the grid sampling protocol.

To measure the air velocities in the shed using the hot-wire anemometer, readings were taken on both sides of the truck and at three different heights (2, 4, and 6 ft). The highest and lowest values observed during the sampling period were recorded. The average sampling period was about one to two minutes per truck. The average wind speed recorded was determined by the anemometer operator. This average was somewhat subjective in that it was the value that the operator believed to be most representative of the range of wind speeds observed. The recorded air velocities are shown in **Tables I-1** through **I-3**.

There were some problems inherent in this procedure. The main problem was continuous changes in wind speed and direction throughout the air sampling period. The anemometer values represent only a small percentage of the time utilized to measure dust emissions from unloading and loading. For example, a truck that required 15 minutes to unload might have only had one to two minutes during which anemometer readings were taken. It was decided that the average air velocities from the weather station data were more consistent than the limited data from the anemometer readings.

Another problem associated with this method was that the average wind speed was a subjective determination by the operator. The average wind speed recorded by the operator was intended to represent the average velocity for the entire sampling time and area..

For Protocol H and I, the grid samplers were used to sample multiple trucks on the same set of filters. The procedure used to calculate the emission factors required the average air velocity through the shed during the air sampling period associated with this air sampling period. The hot-wire anemometer measurements represented air velocities for each individual truck. For example, in **Table I-4**, trucks C12 through C15 were sampled on the same set of filters.

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[5] **This appendix was prepared by Bradley Fritz, Graduate Research Assistant**

The difficulty is that the truck may only take several minutes to load while there was only a minute of anemometer readings taken. The hot-wire anemometer represents only a small percentage of the actual sampling time. The weather station data allows an average velocity to be determined using data taken over the entire sampling period thus giving more accurate readings.

As previously mentioned, the hot-wire anemometer readings were highly variable because of the fluctuations in winds speeds and directions. This made determining an average velocity from the hot-wire anemometer readings difficult at best. The weather station data had wind directions and velocities for the entire sampling time allowing for more reliable averages to be determined. For example, from **Table I-2,** the high wind speed measured for trucks C12 -C15 (one air sampling period) was 750 fpm while the low was 75 fpm. Yet the average found from the weather station data was 262 fpm. The air velocities recorded using the anemometer represented only a fraction of the total sampling time for each period of air sampling.

Table I-4 is a comparison between the wind speeds measured using the hot-wire anemometer and those determined using the weather station data. It was decided that average wind velocities in the shed were better represented by the velocity vectors from the weather station data.

Table I-1: Anemometer Readings: Feed Mill B

Truck #	High Wind Speed (fpm)	Low Wind Speed (fpm)	Average Wind Speed (fpm)	Comments
B01(rear)	150	25	75	High Surge Last Minute
B01(front)	50	25	30	
B02(rear)	100	30	65	
B02(front)	100	25	30	100 fpm was a short surge
B03(rear)	200	40	175	
B03(front)	200	25	100	
B04(rear)	200	25	125	
B04(front)	175	25	100	
B05(rear)	200	75	175	
B05(front)	225	25	125	
B06(rear)	175	25	75	
B06(front)	200	25	50	
B07(rear)	125	25	75	
B07(front)	125	25	75	
B31(rear)	425	375	400	Very Stable
B31(front)	400	350	375	Very Stable

Table I-2: Anemometer Readings: Feed Mill C

Truck #	High Wind Speed (fpm)	Low Wind Speed (fpm)	Average Wind Speed (fpm)	Comments
C06(rear)	750	250	500	Fairly Stable
C06(rear)	750	250	500	Fairly Stable
C07(rear)	700	200	350	Fairly Stable
C07(front)	450	50	300	Fairly Stable
C08(rear & front)	250	0	190	Hard to determine Stable, wind changed direction
C09(rear)	800	350	600	Very Stable
C09(front)	750	50	400	Very Stable
C10(rear)	800	350	600	
C10(front)	1000	450	725	
C12	75	25	50	
C13	600	50	350	Long time interval, much variation
C14	750	200	500	Very Stable
C15	600	400	200	Stable
C16 (1st min)	600	400	500	Stable
C16 (2nd min)	400	150	250	Stable
C16 (3rd min)	550	350	400	Stable
C17 (1st min)	750	400	550	Stable
C17 (2nd min)	450	200	375	Variable
C18	600	75	325	High Variation
C19	1100	500	775	Stable
C20	600	400	500	
C21	750	300	450	
C22	950	500	750	Very Stable
C23	750	400	650	Stable
C24	500	250	350	Stable
C25	450	100	250	High Variation
C26	600	100	350	Some Variation
C27	600	200	375	Variation
C28	400	300	200	
C29	500	200	300	
C30	600	200	400	Stable

Table I-3: Anemometer Readings: Feed Mill D

Truck #	High Wind Speed (fpm)	Low Wind Speed (fpm)	Average Wind Speed (fpm)	Comments
D08	150	150	150	Very Stable
D09	150	150	150	Very Stable
D10	150	150	150	Very Stable
D11	400	300	350	Wrong Way
D12	200	150	175	Wrong Way
D13	300	300	300	Wrong Way
D14	300	300	300	Wrong Way
D15	200	100	150	Stable
D16	150	150	150	Very Stable
D17	300	200	250	Stable
D18	300	150	200	Stable
D19	250	200	225	Stable
D20	500	300	400	Stable
D21	450	350	400	Stable
D22	550	450	500	Stable
D23	500	400	450	Stable
D24	850	750	800	Stable

Table I-4: Wind Velocity Comparison - Hot-Wire Anemometer Vs Weather Station

Truck Number	Average Wind Speeds Used in Emission Factor Calculations (fpm)	Average wind Speeds Hot-Wire Anemometer (fpm)
BO1	40	52
BO2	ERR (Wind Changed Direction)	50
BO3	187	138
BO4	197	113
C06	478	500
C07	361	325
C08	283	190
C09	542	500
C10	647	663
C12*	358	50
C13*	358	350
C14*	358	500
C15*	358	200
C16*	262	575
C17*	262	463
C18*	262	325
C19*	262	775
C20*	262	500
C21*	454	450
C22*	454	750
C23*	454	650
C24*	454	350
C25*	565	250
C26*	565	350
C27*	565	375
C28*	477	200
C29*	477	300
C30*	477	400
D08*	194	150
D09*	194	150
D10*	194	150
D11*	194	350
D12*	297	175
D13*	297	300
D14*	297	300
D15*	297	150
D16*	297	150
D17*	705	250
D18*	705	200
D19*	705	225
D20*	822	400
D21*	822	400
D22*	822	500
D23*	822	450
D24*	822	800

* Each set of trucks (as divided by the lines in the table above) were sampled on the same set of filters. This required that one average air velocity be determined for the entire set. Hot-wire anemometer reading were taken for each individual truck, as shown in the table.